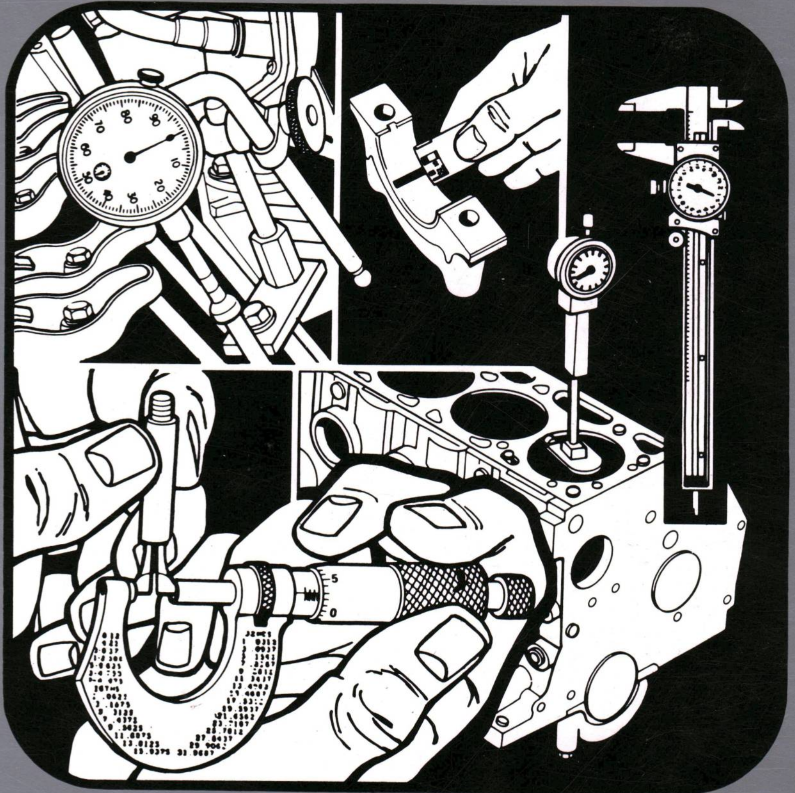
automotive measuring devices & systems



Supplement to Select STST Courses

[redacted]

STST

Service Technician Specialty Training

Ford Parts and Service Division
Technical Training

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across NOTES, CAUTIONS, AND WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine on) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind the head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure the electrical cooling fan is completely disconnected when working under the hood.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents if available may be used. The right is reserved to make changes at any time without notice.

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Technical Training
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INTRODUCTION

This reference manual covers the description, selection and use of various automotive measuring devices. It also contains descriptions of pressure, temperature and distance measurement systems applicable to automotive concerns. This information is organized into the following four general categories:

- Mechanical Measurement Devices
- Electrical Measurement Devices
- Pneumatic Measurement Devices
- Hydraulic Measuring Devices

This manual is intended to serve as a guide for measuring device selection, description and usage. Technicians of all experience levels will find the information in this reference manual to be useful. Experienced technicians can review their knowledge of seldom-used tools; technicians with limited experience will be able to research the "hows and whys" of automotive measurement devices.

Many dealerships do not perform major machine work "in house." However, information about several specialized tools and procedures is included in this manual. This information will aid the technician in the inspection and preparation of parts which are sent to the machine shop.

THE IMPORTANCE OF ACCURATE MEASUREMENTS

The durability and service life of all types of machinery depends upon how long the equipment remains within specifications. During assembly, parts of exactly the right size must be selected in order to create smooth-running and long-lasting equipment. This selection process requires accurate measurements.

When an assembly becomes worn, proper rebuilding procedures can restore it to specifications. But there are often variations between replacement parts and the original components. Therefore, it is essential to make critical dimension checks and exact measurements during rebuilding procedures. These measurements ensure that all parts and assemblies are precisely fitted to ensure maximum reliability of the rebuilt unit.

Ultimately, the success of most automotive service procedures depends on the accuracy of the measurements which distinguish good components from bad ones, proper adjustments from incorrect ones, and good performance from poor performance. Without the information provided by precise measurements, everything from diagnosis to overhaul is based on mere guesswork.

OBJECTIVES

Technicians who carefully study Automotive Measuring Devices and Systems can expect to gain the following advantages:

- The ability to describe automotive measuring devices.
- The ability to give examples of measuring tool usage.
- The ability to describe various measurement systems and their relationship to automotive measurement devices.
- The ability to use various measurement devices and systems to obtain physical information about automotive components.

MECHANICAL MEASURING DEVICES

HANDLING PRECISION MEASURING INSTRUMENTS

Measuring tools are precise and delicate instruments. In fact, the more precise they are, the more delicate they are. They should be handled with great care. When you are using a measuring device, you should always place it so that it cannot fall or strike other tools. You should never pry, strike, drop or force these instruments; they might be damaged beyond useability.

Precision measuring instruments, especially micrometers, are extremely sensitive to rough handling. You must clean them before and after every use. Never touch the measuring surfaces of the micrometer. Fingerprints can help rust to form, and body heat can affect accuracy. All measuring operations must be performed on room temperature parts. Never measure parts which are still warm from machining operations.

Micrometers must be stored properly. Never store a micrometer with the measuring surfaces together. If a micrometer stored in this way experiences any temperature changes, it might be damaged ("sprung"). An improperly stored micrometer may become worthless as a measuring tool.

You must use great care when you handle and store your precision measuring instruments. Otherwise, you may find yourself carefully obtaining inaccurate measurements.

NOTE: Check your measuring instruments regularly against known good equipment to ensure that they are operating properly and capable of accurate measurement.

NOTE: Always refer to the appropriate shop manual or other reference material for the correct specifications before performing service or diagnosis procedures. The close tolerances in current vehicles makes using the correct specifications and taking accurate measurements more important than ever.

MACHINIST'S RULES

The machinist's rule looks like an ordinary ruler (Fig. 1). However, unlike the common ruler, it is precisely divided into small (1/64-inch) increments. A typical machinist's rule is marked on both sides. One side is marked off at 1/16-, 1/8-, 1/4-, 1/2- and one-inch intervals. The other side is marked at 1/32- and 1/64-inch intervals.

Machinist's rules are also available with metric or decimal graduations. Metric rules are usually divided into 1mm and 1/2mm increments. Decimal rules are typically divided into 1/10-, 1/50- and 1/100-inch (0.10, 0.50 and 0.01-inch) increments. Decimal machinist's rules are convenient when measuring component dimensions which are specified in decimals.

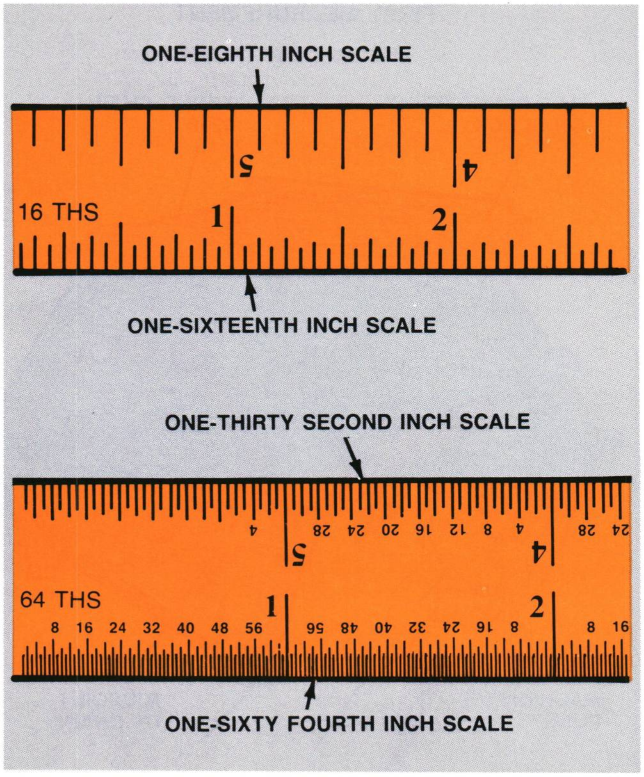


Figure 1 — Typical Machinist's Rule Graduations

Timing Chain Deflection Check

Machinist's rules are used in procedures like the timing chain deflection check. Timing chain deflection checks are performed as follows:

(Refer to Fig. 2.)

1. Remove the chain tensioner and retaining bolts if the engine is so equipped.
2. Rotate the crankshaft clockwise (as viewed from the front of the engine) to take up slack on the right side of the chain.
3. Mark a reference point on the block at the approximate midpoint of the chain. Measure from this point to the midpoint of the chain.
4. Rotate the crankshaft counterclockwise to take up slack on the left side of the chain.
5. Force the left side of the chain outward with your finger and measure the distance between the reference point and the midpoint of the chain.
6. Timing chain deflection is the difference between the two measurements. Replace the timing chain and gears if the deflection measurement exceeds specifications.

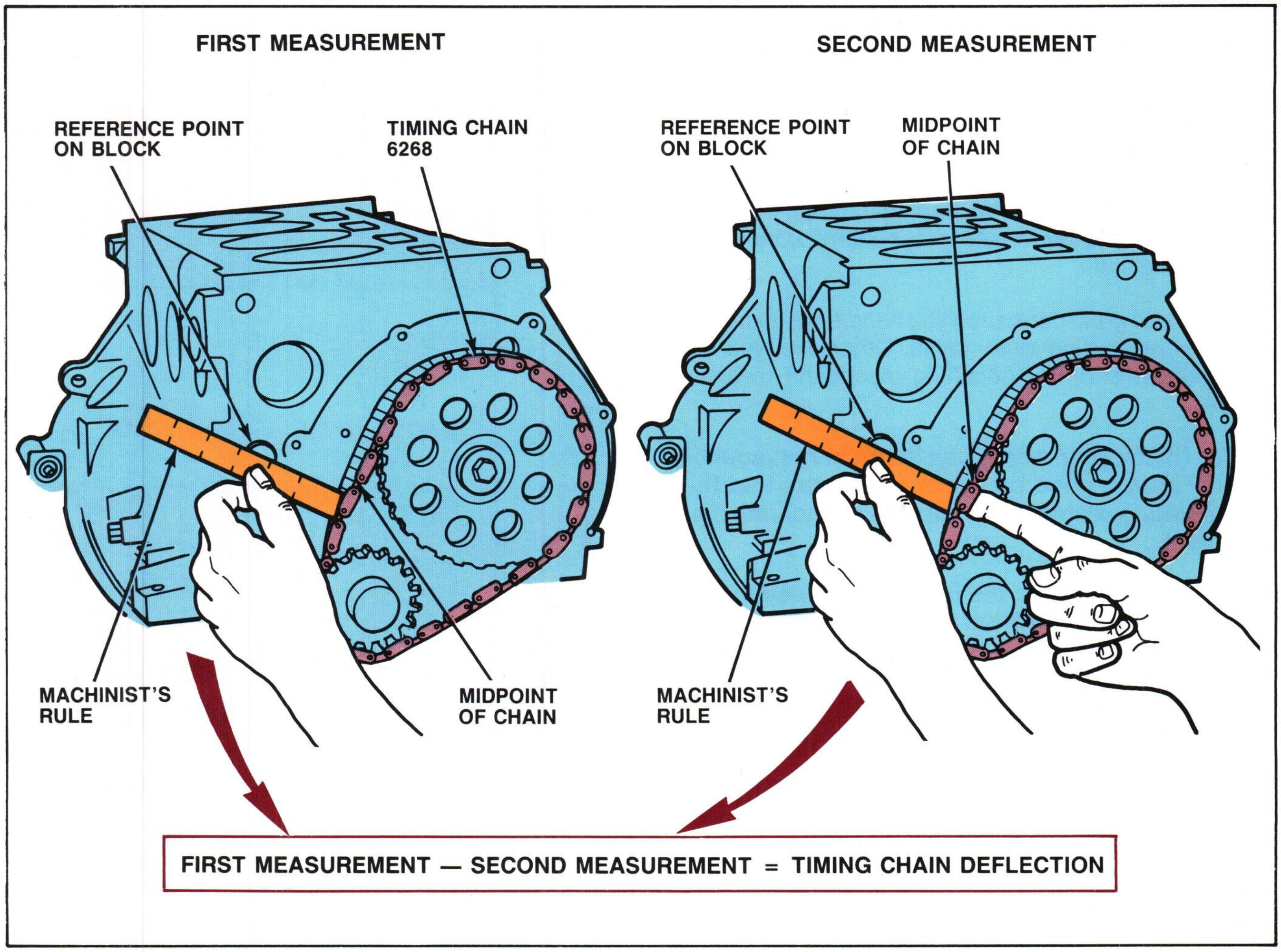


Figure 2 — Timing Chain Deflection Check

FEELER GAUGE

The feeler gauge is a strip of metal of known and closely controlled thickness. Several of these metal strips are often combined into a multiple measuring instrument that pivots in a manner similar to a pocket knife (Fig. 3). The desired thickness gauge may be pivoted away from others for convenient use.

The feeler gauge may be used by itself to measure piston ring side clearance, piston ring end gap, connecting rod side clearance, crankshaft end play and other similar procedures. The feeler gauge can also be used with a straightedge (Fig. 3) to measure main bearing bore alignment and cylinder head/block warpage.

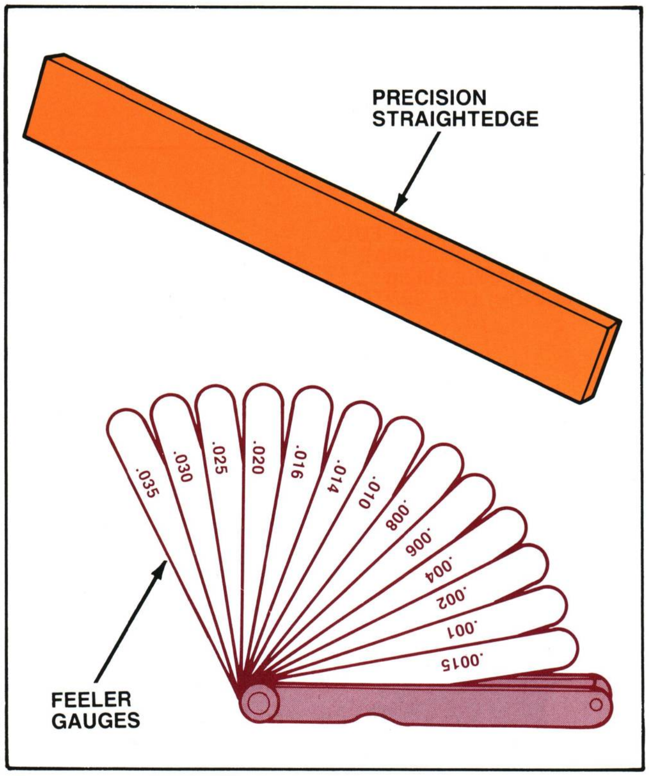


Figure 3 — Precision Straightedge and Feeler Gauge

Piston Ring Side Clearance

You may use a feeler gauge to measure piston ring side clearance as follows (Fig. 4):

1. Install the correct ring into the top groove of the piston.
2. Insert progressively thicker feeler gauges into the space between the top of the ring and the piston groove.
3. When you have determined the thickest gauge which will fit between the piston ring and ring groove, the thickness of that gauge equals the piston ring side clearance measurement.

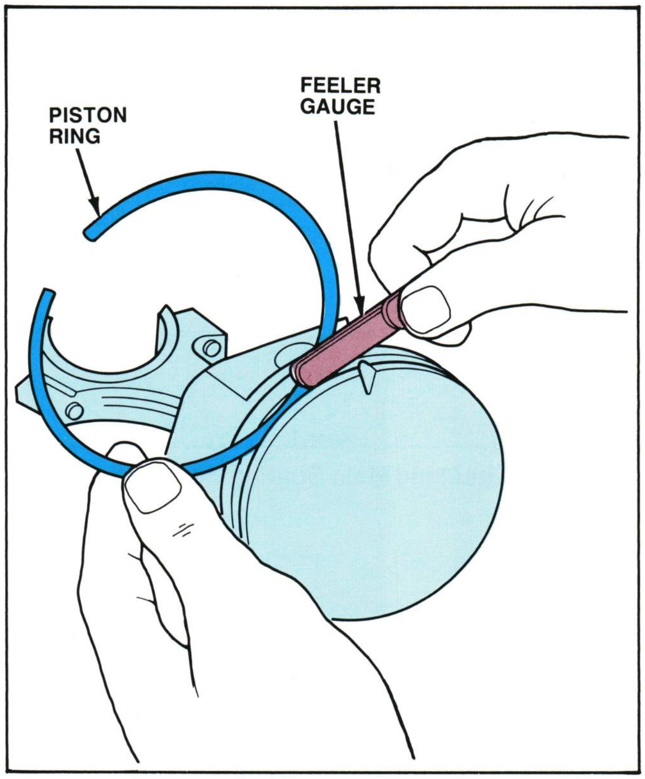


Figure 4 — Measuring Piston Ring Side Clearance Using a Feeler Gauge

MECHANICAL MEASURING DEVICES

PRECISION STRAIGHTEDGE

The precision straightedge is just what its name implies: a very flat, straight bar which is compared to various surfaces to determine the flatness of an object. The precision straightedge is often used with the feeler gauge to measure main bearing bore alignment (Fig. 5), cylinder block warpage and cylinder head warpage.

The straightedge is placed against the component to be inspected. Then, various feeler gauges are slipped between the component and straightedge. The readings are compared to the specification. You must then decide whether or not the component (in this case a cylinder block) must be align bored.

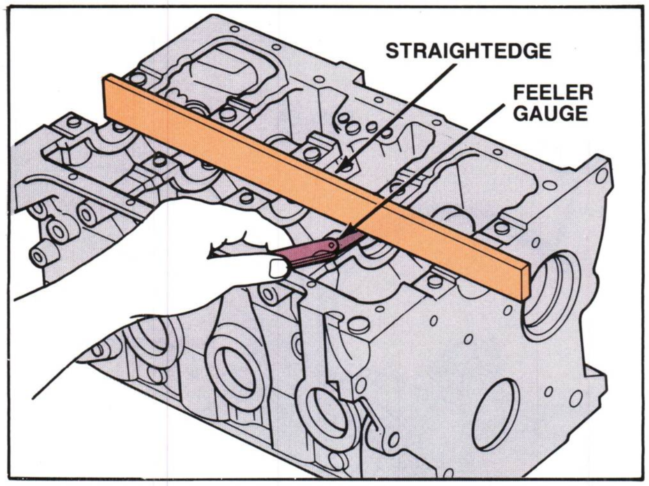


Figure 5 — Checking Main Bearing Bore Alignment

PLASTIGAGE

Plastigage (Fig. 6) is a trademarked measuring tool. It is used to check main and connecting rod bearing clearances. When it is placed between the bearing and journal, the pressure of bearing cap installation torque flattens it. The flattened Plastigage is then compared to a measuring scale (Fig. 6) to determine bearing clearance. Before flattening, Plastigage resembles monofilament fishing line.

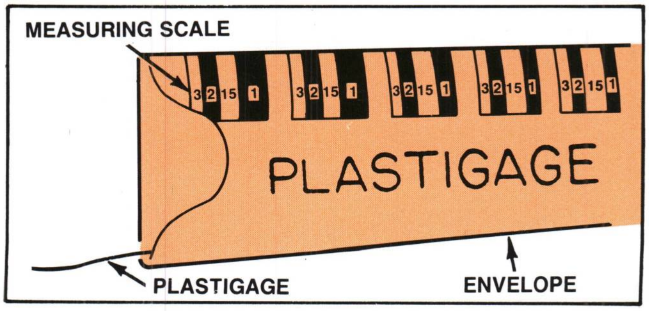


Figure 6 — Plastigage

Bearing Clearance Check (Typical)

You may use Plastigage to measure bearing clearance as follows (Fig. 7):

1. Place a piece of Plastigage across the bearing journal approximately onequarter inch off center.
2. Install the cap with the bearing and tighten the bolts to specification. Do not rotate the crankshaft while the Plastigage is in place.
3. Remove the bearing cap. Compare the width of the flattened Plastigage with the measuring scale printed on the envelope. Measure the width of the Plastigage at its widest point to obtain a reading of minimum clearance. Measure the Plastigage at its narrowest point to obtain a reading of maximum clearance.
4. Remove the Plastigage.

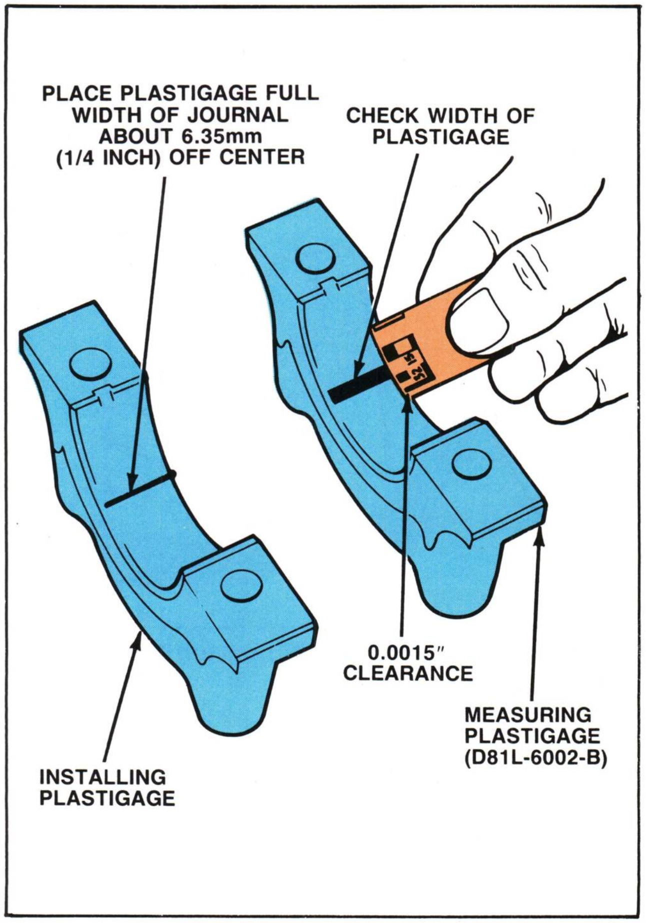

PLACE PLASTIGAGE FULL WIDTH OF JOURNAL ABOUT 6.35mm (1/4 INCH) OFF CENTER
CHECK WIDTH OF PLASTIGAGE
0.0015″ CLEARANCE
MEASURING PLASTIGAGE (D81L-6002-B)
INSTALLING PLASTIGAGE

Figure 7 — Installing and Measuring Plastigage

MECHANICAL MEASURING DEVICES

SPRING SCALE

The spring scale is a measuring device which is commonly used to check the articulation effort of tie rods, rack-and-pinion assemblies and steering gears. The spring scale contains a calibrated spring which compresses a known amount under a given load (0-10 lbs.). To use it, support the upper end and hang the load from the loop provided on the bottom of the scale. With the hanging load still applied, read the indicated force on the divisions marked on the barrel.

Checking Tie Rod Articulation Effort (Typical)

To measure tie rod articulation effort, perform the following procedure (Fig. 8):

1. Loop some wire through the hole in the tie rod end stud. Insert the hook of the spring scale through the wire loop.
2. Raise the upper loop of the spring scale until the the tie rod moves. The typical effort required to move the tie rod after initial breakaway should be 3.1-22.2N (0.7-5.0 lbs). Refer to the applicable service publication for specifications.

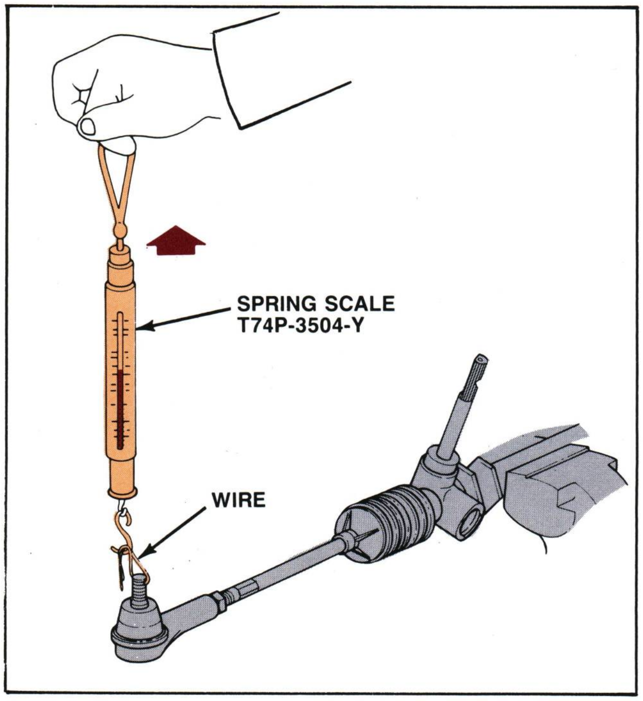


Figure 8 — Measuring Tie Rod Articulation Effort Using Spring Scale

VALVE/CLUTCH SPRING TESTER

The valve/clutch spring tester measures the amount of force required to compress a valve spring at its installed height. It is necessary to check valve spring pressure because weak valve springs cause poor engine performance. If valve spring pressures are lower than the service limit, the spring must be replaced.

Checking Valve Spring Pressure (Typical)

To check valve spring pressure, use a torque wrench and valve/clutch spring tester as follows (Fig. 9):

1. Place the valve spring into the checking fixture. Turn the height adjustment knob until the specified compressed spring height is obtained.
2. Attach a torque wrench to the spring tester lever arm as illustrated.
3. Apply torque to the spring tester until you hear a click.
4. Multiply the torque wrench reading by two to obtain the valve spring pressure.

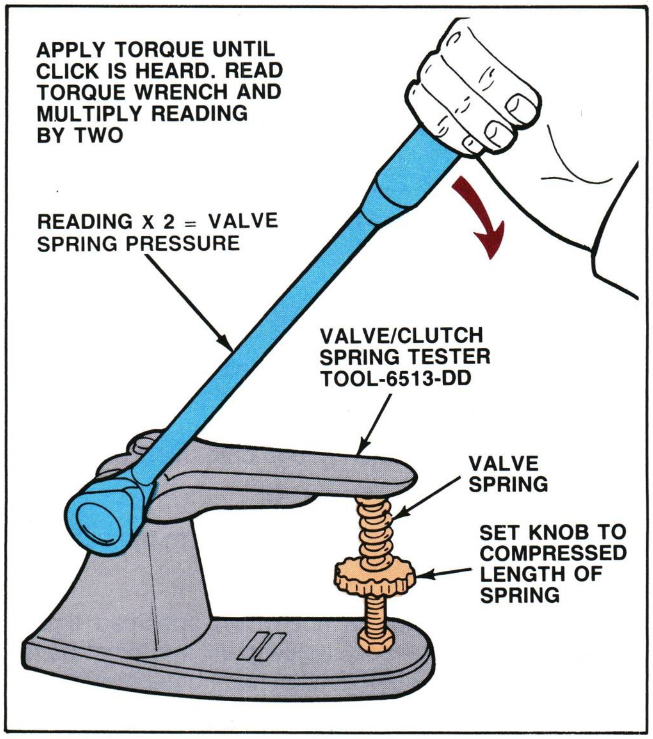

APPLY TORQUE UNTIL CLICK IS HEARD. READ TORQUE WRENCH AND MULTIPLY READING BY TWO
READING X 2 = VALVE SPRING PRESSURE
VALVE/CLUTCH SPRING TESTER TOOL-6513-DD
VALVE SPRING
SET KNOB TO COMPRESSED LENGTH OF SPRING

Figure 9 — Measuring Valve Spring Pressure

MECHANICAL MEASURING DEVICES

BELT TENSION GAUGE

The belt tension gauge permits you to accurately adjust accessory drive belt tension. Drive belts which are improperly adjusted can cause conditions like overheating, noise complaints and charging system complaints. Loose belts slip; they do not drive accessories at the proper operating speeds. Overly-tight belts place severe loads on accessory bearings, often causing premature component failure.

The belt tension gauge works equally well on both "V" and "V-ribbed" drive belts. Accessory drive systems like the serpentine belt type which use automatic tensioners do not require adjustment. The gauge is only intended for use on accessory drive systems which are not equipped with an automatic tensioner.

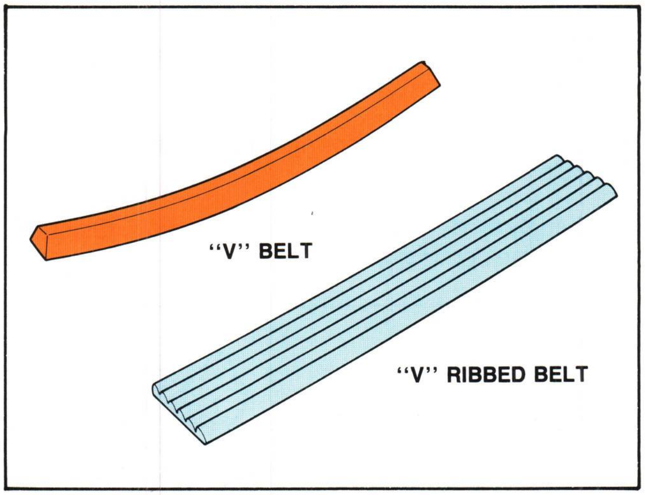


Figure 10 — Accessory Drive Belt Types

Checking Drive Belt Tension (Typical)

To adjust drive belt tension, use belt tension gauge as follows (Fig. 11):

1. Place the belt tension gauge onto the drive belt as illustrated.
2. Obtain a reading of belt tension from the scale on the side of the gauge.
3. If the belt tension is not within specified limits, loosen the accessory adjustment and pivot bolts. Then, adjust the belt tension and tighten the accessory adjustment and pivot bolts.
4. Check and readjust belt tension if necessary.

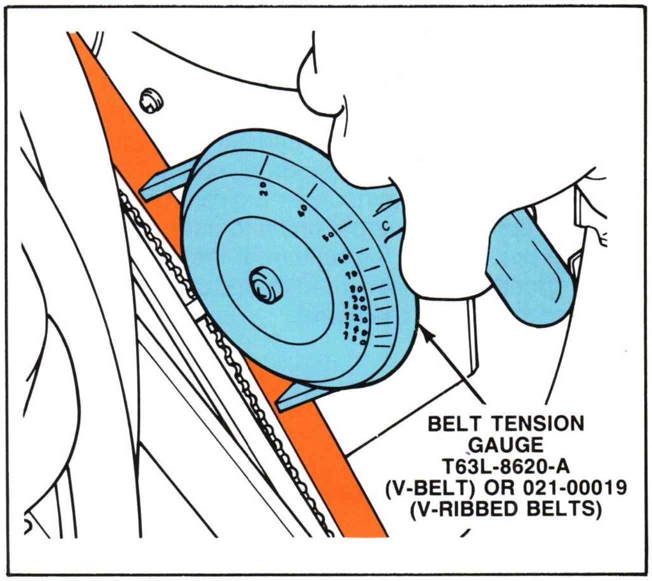


Figure 11 — Adjusting Belt Tension Using a Belt Tension Gauge

BRAKE PEDAL EFFORT GAUGE

The brake pedal effort gauge (Fig. 12) is used to check brake pedal free height, travel and compression. Brake pedal effort gauges are typically available in calibrations of either 0-160 lbs. (car) or 0-300 lbs. (truck).

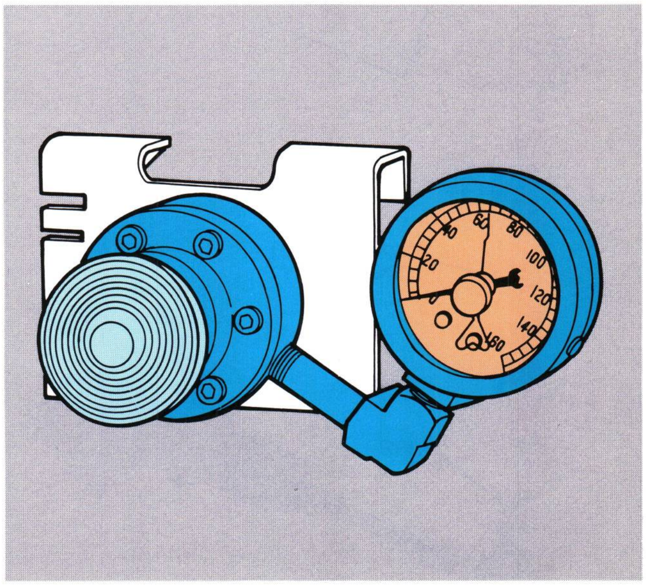


Figure 12 — Typical Brake Pedal Effort Gauge

Measuring Brake Pedal Travel (Typical)

To measure brake pedal travel perform the following procedure (Fig. 13):

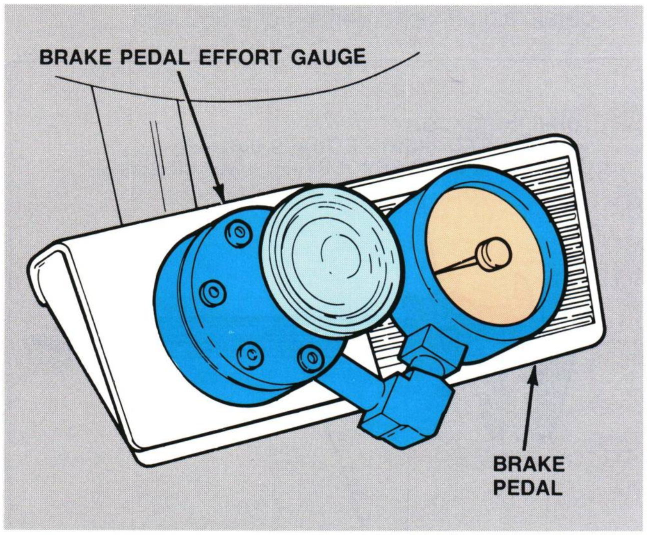


Figure 13 — Brake Pedal Effort Gauge Installed Onto Pedal

1. Install the brake pedal effort gauge onto the brake pedal pad.
2. Hook a steel measuring tape to the brake pedal. Measure and record the distance from the brake pedal free height position to the reference point, which is at the six o'clock position on the steering wheel rim.
3. With the steel tape still hooked to the brake pedal, depress the brake pedal by pressing downward on the brake pedal effort gauge. Apply a 111 N (25 lb) load to the center of the pedal. Maintain the pedal load and measure the distance from the brake pedal to the fixed reference point on the steering wheel rim parallel to the centerline of the steering column.
4. The difference between the brake pedal free height and the depressed pedal measurement under a 111 N (25 lb) load should be as specified in the applicable service publication.

DIAL CALIPER

The dial caliper (Fig. 14) is a versatile measuring instrument. It is capable of taking inside, outside, depth and step measurements. It can measure these dimensions from 0-6 inches. Metric dial calipers typically measure from 0-150mm in increments of 0.02mm.

The dial caliper features a depth scale, bar scale, dial indicator, inside measurement jaws and outside measurement jaws. The bar scale is divided into one-tenth (0.10) of an inch graduations. The dial indicator is divided into one-thousandth (0.001) of an inch graduations. Therefore, one revolution of the dial indicator needle equals one-tenth of an inch on the bar scale (one hundred-thousandths of an inch equals one-tenth of an inch).

The metric dial caliper is similar in appearance to the U.S. (inch reading) model. However, the bar scale is divided into 2mm increments. Additionally, on the metric dial caliper, one revolution of the dial indicator needle equals 2mm.

Both inch reading and metric dial calipers use a thumb-operated roll knob for fine adjustment. When you use a dial caliper, always move the measuring jaws backward and forward to center the jaws in the work. Always make sure that the the caliper jaws lay flat on the work. If the jaws or the work are tilted in any way, you will not obtain an accurate measurement.

However, while dial calipers are precision measuring instruments, they are only accurate to within ± 0.002 inches. The factors which limit dial caliper accuracy include jaw flatness and "feel." Micrometers are better suited to measuring tasks which require extreme precision.

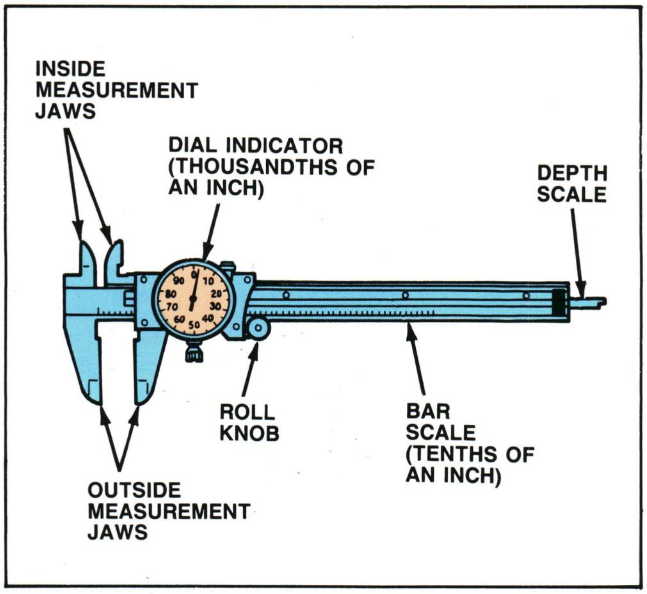


Figure 14 — Typical Dial Caliper

Measuring With a Dial Caliper (Typical)

To obtain inside or outside measurements with a dial caliper, perform the following procedure (Fig. 15):

1. Place the object to be measured into/onto the appropriate measuring jaws.
2. Move the measuring jaws into contact with the object to be measured.
3. Using the roll knob, move the jaws back and forth to ensure that the work is precisely centered and flat between the jaws.
4. Count the number of visible graduations on the bar scale. On inch-graduated dial calipers, each mark on the bar scale equals 0.1 (one-tenth of an inch). On metric dial calipers, each mark on the bar scale equals 2mm (two millimeters).
5. Count the number of graduations shown on the dial indicator. On inch-graduated calipers, dial indicator marks equal 0.001 inch (one-thousandth of an inch). On metric calipers (Fig. 16), each dial indicator mark equals 0.01mm (one-hundredth of a millimeter).
6. Add the bar scale and dial indicator readings together to derive the final measurement.
7. Figure 15 illustrates a measurement of 0.602 inches. This measurement is derived as follows: Six marks are visible on the bar scale (0.6 inches). The dial indicator reads two-thousandths of an inch. When you add 0.6 inch and 0.002 inch together, you obtain a final measurement of 0.602 inch.

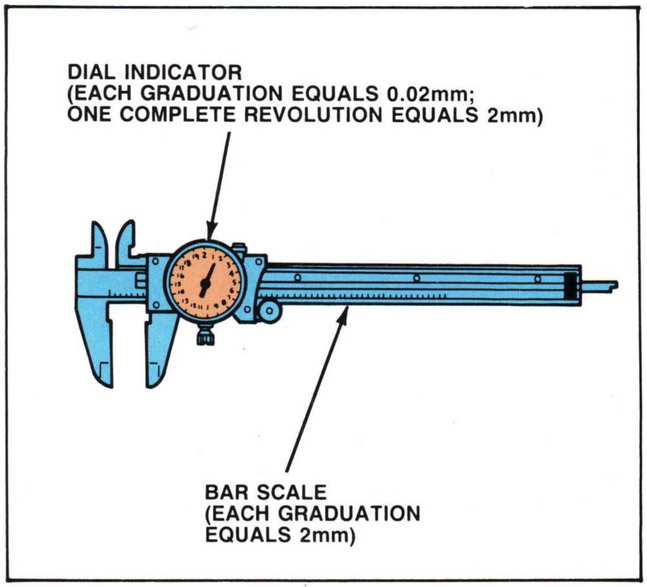

DIAL INDICATOR
(EACH GRADUATION EQUALS 0.02mm;
ONE COMPLETE REVOLUTION EQUALS 2mm)
BAR SCALE
(EACH GRADUATION
EQUALS 2mm)

Figure 16 — Metric Dial Caliper

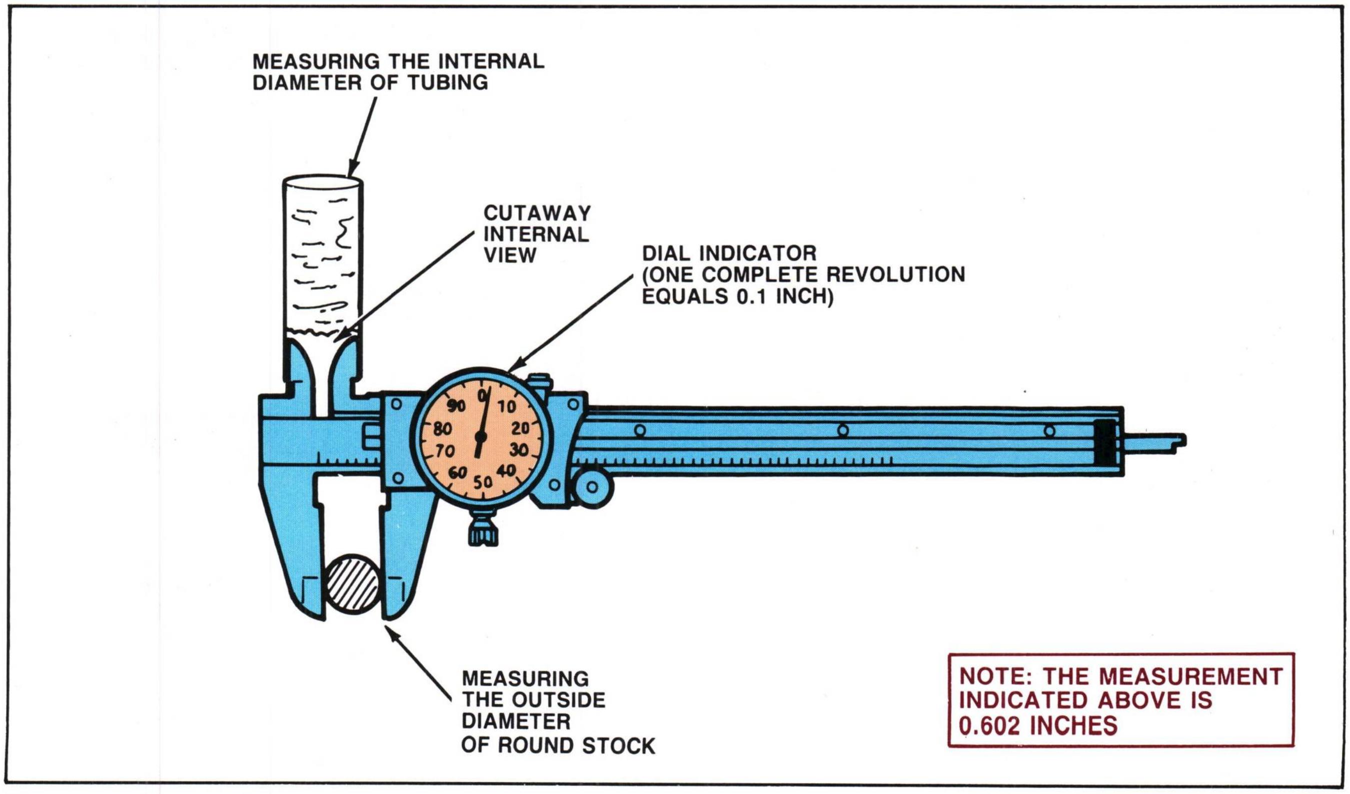


Figure 15 — Measuring Inside and Outside Diameter Using an Inch-Graduated Dial Caliper

DIAL INDICATORS

The dial indicator (Fig. 17) is calibrated in 0.001-inch (one-thousandth of an inch) increments. Metric dial indicators are also available. Both types are used to measure movement. Common uses of the dial indicator include measuring valve lift, journal concentricity, flywheel or brake rotor runout, gear backlash and crankshaft end play.

Dial indicators are available with various face markings and measurement ranges to accommodate many measuring tasks. Some dial indicators are equipped with a revolution counter (Fig. 18) that helps you keep track of how many revolutions the indicator needle has completed. Additionally, several mounting fixtures and adapters attach to the dial indicator to make it an accurate and versatile measuring instrument.

Measuring With a Dial Indicator (Typical)

To use a dial indicator, position the indicator rod against the object to be measured. Then, push the indicator toward the work until the indicator needle travels far enough around the gauge face to permit movement to be read in either direction. Zero the indicator needle on the gauge. Always be sure that the range of the dial indicator is sufficient to allow the amount of movement required by the measuring operation. For example, do not use a one-inch indicator on a component which will move two inches.

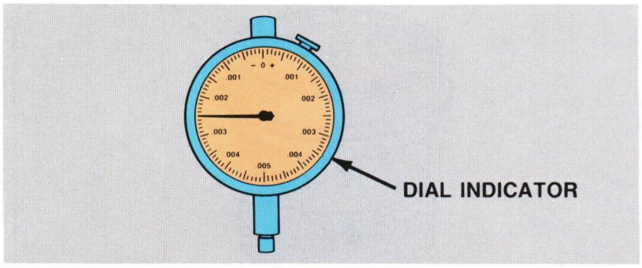


Figure 17 — Dial Indicator For Measuring Plus/Minus 0.0001 Inch

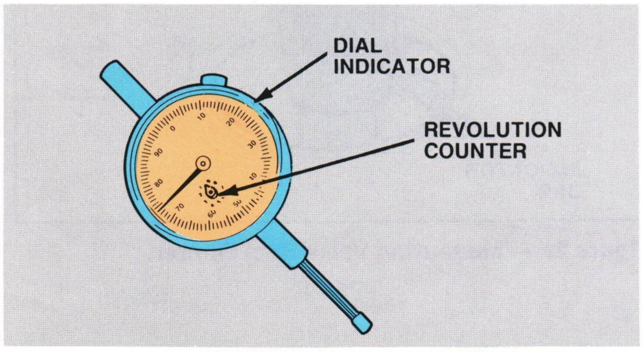


Figure 18 — Dial Indicator with Revolution Counter

Checking Cam Lobe Lift (Typical)

NOTE: Check the lift of each cam lobe in consecutive order and make a note of readings.

To measure camshaft lobe lift using a dial indicator, perform the following procedure (Fig. 19):

1. Remove the throttle body and the valve rocker arm cover(s).
2. Ensure that the push rod is in the valve tappet socket. Install the dial indicator so that the cup shaped adapter fits onto the end of the push rod and is in the same plane as push rod movement.
3. Connect an auxiliary starter switch into the starting circuit. Crank the engine with the ignition switch off. "Bump" the crankshaft over until the tappet is on the base circle of the camshaft lobe. At this point, the push rod will be in its lowest position.
4. Zero the dial indicator. Continue to rotate the crankshaft slowly until the push rod is in its fully raised position (highest indicator reading).
5. Compare the total lift recorded on the indicator with specifications.
6. To check the accuracy of the original indicator reading, continue to rotate the crankshaft until the indicator reads zero. **If lift on any lobe is below specified service limits, the camshaft and tappets operating on the worn lobe(s) must be replaced. Any tappet showing pitting or having its contact face worn flat or concave must also be replaced.**

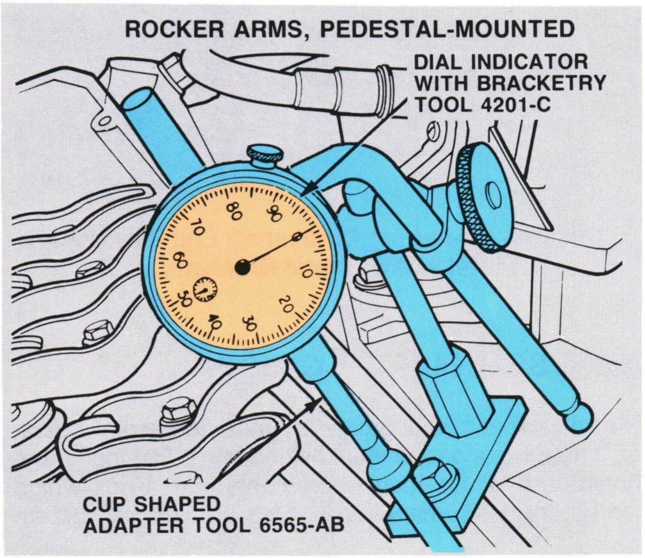

ROCKER ARMS, PEDESTAL-MOUNTED
DIAL INDICATOR WITH BRACKETRY TOOL 4201-C
CUP SHAPED ADAPTER TOOL 6565-AB

Figure 19 — Checking Camshaft Lobe Lift Using a Dial Indicator

Checking Crankshaft End Play (Typical)

To measure crankshaft end play using a dial indicator and bracketry, perform the following procedure (Fig. 20):

1. Force the crankshaft toward the rear of the engine.
2. Install a dial indicator and bracketry so that the contact point rests against the crankshaft flange, and the indicator axis is parallel to the crankshaft axis.
3. Zero the dial indicator. Push the crankshaft forward and note the reading on the dial.
4. If the end play exceeds the specified wear limit, replace the thrust bearing. If the end play is less than the minimum limit, inspect the thrust bearing faces for scratches, burrs, nicks or dirt. If the thrust faces are not damaged or dirty, they probably were not aligned properly.

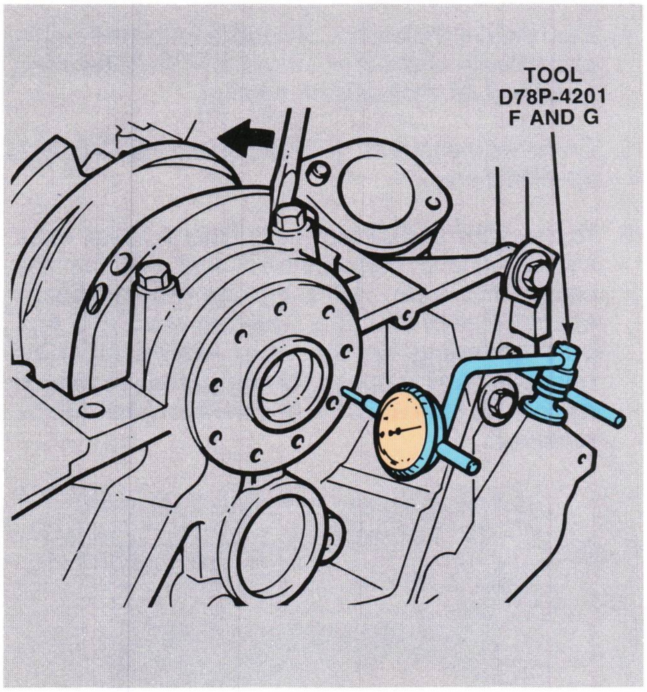


Figure 20 — Measuring Crankshaft End Play Using a Dial Indicator and Bracketry

VALVE SEAT RUNOUT GAUGE

The valve seat runout gauge is similar to the dial indicator. It features a gauge face divided into 0.001-inch (one-thousandth of an inch) increments, an arbor which centers the instrument in the valve guide bore, and an indicator bar which can be adjusted so that it bears on the valve seat. The tool is then slowly rotated around the circumference of the valve seat to check its concentricity (runout).

Checking Valve Seat Runout (Typical)

To measure valve seat runout after machining, perform the following procedure:

1. Mount the runout gauge along with the arbor into the valve guide so that the indicator bar contacts the center of the valve seat (Fig. 21).
2. Set the dial to "0."
3. Hold the dial section and slowly turn the lower section so that the bar travels around the seat.
4. The dial needle will indicate any runout. Typically, the runout should be within 0.050mm (0.002 inch). Refer to specifications in the applicable service publication.
5. If runout exceeds specifications, check the dial indicator setup and repeat the procedure.
6. If runout is still present, the seat must be reground and checked again.

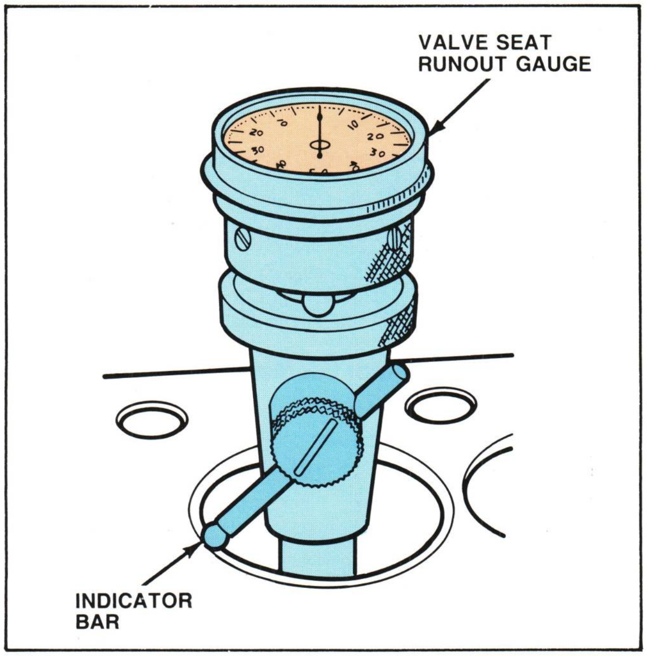


Figure 21 — Measuring Valve Seat Runout

CYLINDER BORE DIAL GAUGE

The cylinder bore dial gauge is used to rapidly and accurately determine cylinder bore out-of-round and taper. These two measurements, in addition to main bearing saddle alignment, provide basic information about the condition of the cylinder block. A block outside specification in any of these areas requires machining to restore it to specified tolerances.

Cylinder bore dial gauges are read in the same way that a dial indicator is read. As with the inside micrometer and telescoping gauge, the cylinder bore micrometer must be rocked in order to obtain the correct measurement.

The parts of the cylinder bore dial gauge include the handle, guide blocks, lock, indicator contact and dial indicator (Fig. 22). Various indicator contacts can be installed in order to measure several bore sizes with one gauge.

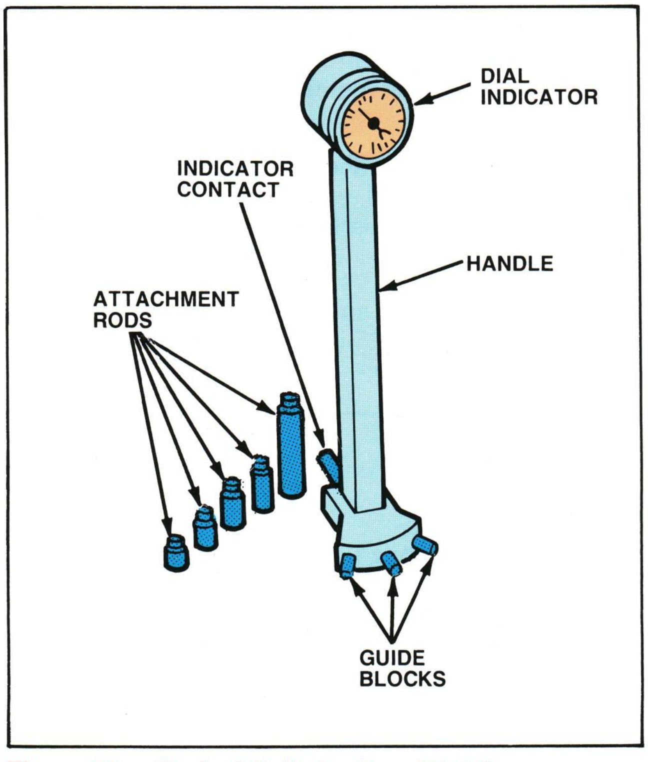


Figure 22 — Typical Cylinder Bore Dial Gauge

Cylinder bores do not always wear in a perfectly round pattern; one side of the cylinder wall usually wears more than the other. For this reason, cylinder roundness must be determined (Fig. 23). To measure out-of-round, measure the cylinder bore at uniform depth in three directions (front/rear, right/left, and diagonally) (Fig. 24). Then, the smallest reading obtained from the cylinder is subtracted from the largest reading. The resulting figure is cylinder bore out-of-round.

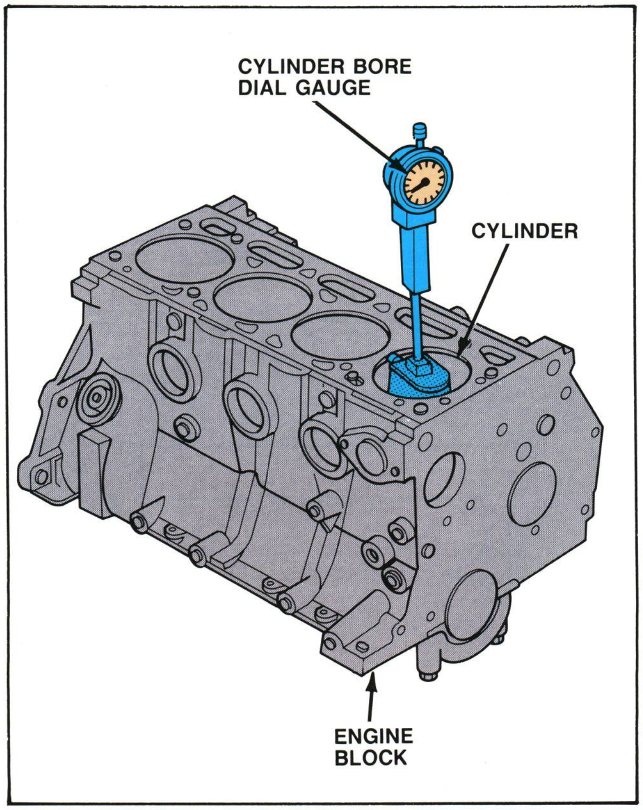


Figure 23 — Measuring Cylinder Bore Out-of-Round and Taper Using a Cylinder Bore Dial Gauge

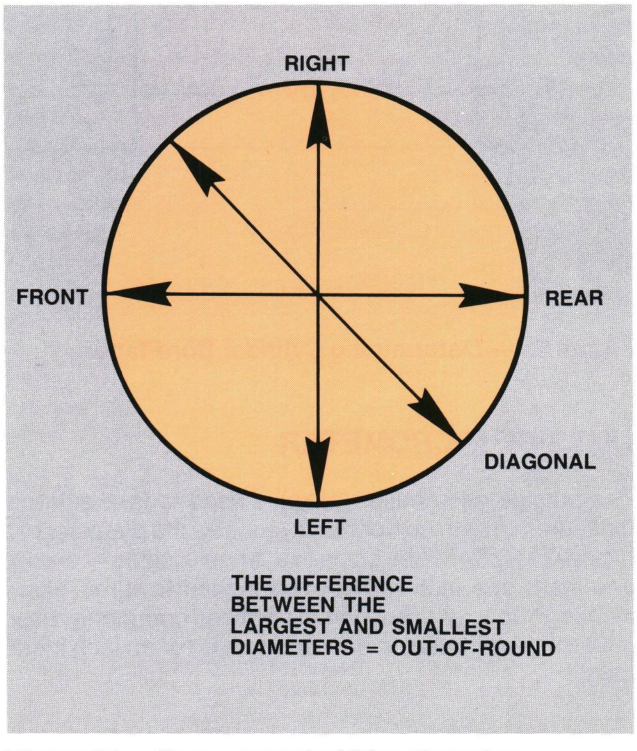

RIGHT
FRONT
REAR
DIAGONAL
LEFT
THE DIFFERENCE BETWEEN THE LARGEST AND SMALLEST DIAMETERS = OUT-OF-ROUND

Figure 24 — Recommended Directions for Measuring Cylinder Bore Out-of-Round

Checking Cylinder Bore Taper (Typical)

To determine cylinder bore taper, first center the dial gauge near the top of the cylinder and obtain a reading. Then, measure the cylinder near the bottom of the bore. Finally, subtract the smaller of the two measurements from the largest reading (Fig. 25). The resulting figure is cylinder bore taper. If cylinder bore taper is outside specification, the cylinder must be rebored.

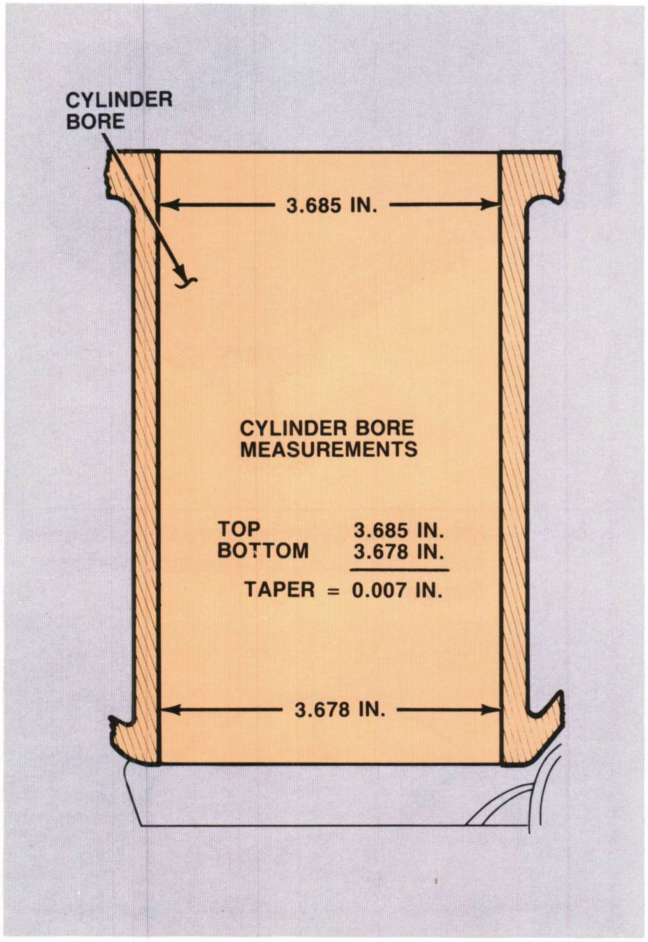


Figure 25 — Determining Cylinder Bore Taper

OUTSIDE MICROMETER

The outside micrometer (mike) is used to take external measurements of components, such as the diameter of a piston (Fig. 26). Mikes come in a range of sizes — zero to one inch, one inch to two, two inches to three, three inches to four and beyond. The most commonly used mikes are calibrated in one-thousandth of an inch increments.

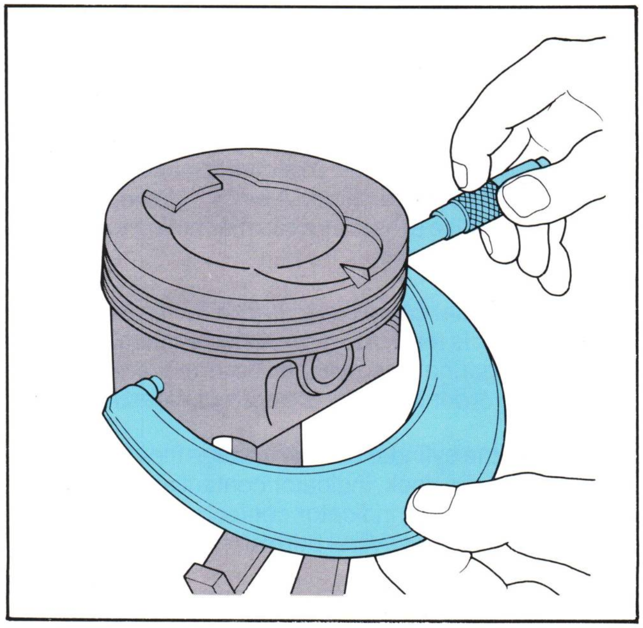


Figure 26 — Using an Outside Micrometer to Measure Piston Diameter

The major components and markings of the micrometer include the frame, anvil, spindle, lock nut, sleeve numbers, thimble marks, thimble, sleeve long line, and the ratchet screw (Fig. 27).

Micrometers are made so that each turn of the thimble moves the spindle 0.025 inch (twenty-five thousandths of an inch).

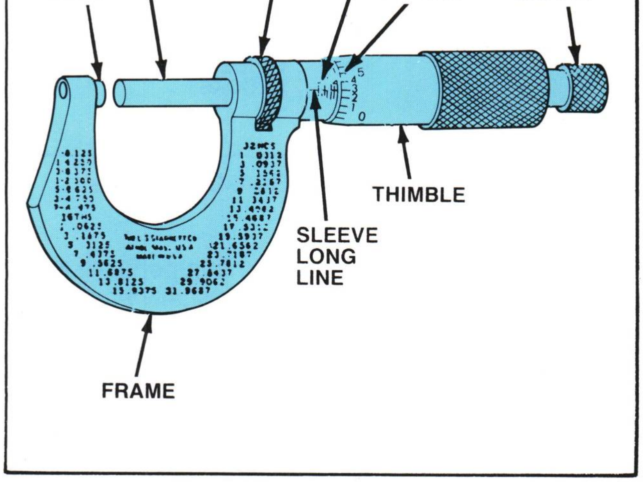


Figure 27 — Typical Outside Micrometer Components and Markings

This is accomplished by using forty threads per inch on the thimble. The sleeve long line is marked with sleeve numbers 1, 2, 3, etc. These sleeve numbers represent 0.100 inch, 0.200 inch, 0.300 inch, etc. (one-tenth of an inch, two-tenths, three-tenths, etc.). The sleeve of the micrometer contains sleeve marks which represent one inch in 0.025-inch (twenty-five thousandths of an inch) increments. Each of the thimble marks represents .001 inch (one-thousandth of an inch). In one complete turn, the spindle will move 25 marks or 0.025 inch (twenty-five thousandths of an inch). Some micrometers also include a vernier scale which is used to indicate 0.0001 inch (one ten-thousandth of an inch). This vernier scale will be described in detail later.

READING MICROMETERS (INCH-GRADUATED)

To read the micrometer, first read the last whole sleeve number visible on the sleeve long line. Next, count the number of full sleeve marks past the number. Finally, count the number of thimble marks past the sleeve marks. Add these measurements together and you have your measurement. These three readings indicate tenths, hundredths and thousandths of an inch respectively. For example, a 2- to 3-inch micrometer that has taken a measurement is described as follows (Fig. 28):

1. The largest sleeve number visible is 4. This indicates 0.400 inch (four-tenths inches).

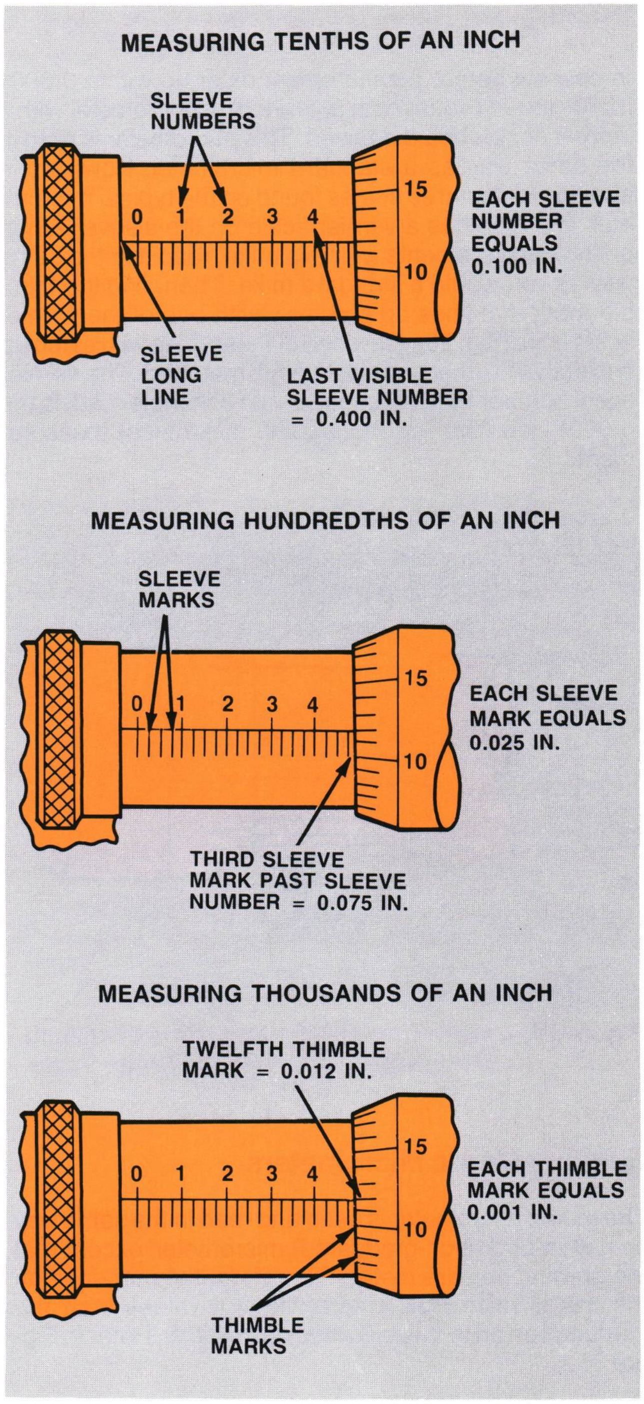
2. The thimble is 3 full sleeve marks past the sleeve number. Each sleeve mark indicates 0.025 inch, so this indicates 0.075 inch (seventy-five hundredths of an inch).

3. The number 12 thimble mark is lined up with the sleeve long line. This indicates 0.012 inch (twelve-thousandths of an inch).

4. Add the readings from steps 1, 2 and 3. The total of the three is the correct reading. In our example:

Sleeve number	0.400 inch
Sleeve marks	0.075 inch
Thimble marks	0.012 inch
Total	= 0.487 inch

5. Now add 2 inches to the measurement, since this is a 2- to 3-inch micrometer. The final reading is 2.487 inches.


MEASURING TENTHS OF AN INCH

SLEEVE NUMBERS
0
1
2
3
4
15
10
EACH SLEEVE NUMBER EQUALS 0.100 IN.
SLEEVE LONG LINE
LAST VISIBLE SLEEVE NUMBER = 0.400 IN.

MEASURING HUNDREDTHS OF AN INCH

SLEEVE MARKS
0
1
2
3
4
15
10
EACH SLEEVE MARK EQUALS 0.025 IN.
THIRD SLEEVE MARK PAST SLEEVE NUMBER = 0.075 IN.

MEASURING THOUSANDS OF AN INCH

TWELFTH THIMBLE MARK = 0.012 IN.
0
1
2
3
4
15
10
EACH THIMBLE MARK EQUALS 0.001 IN.
THIMBLE MARKS

Figure 28 — The Three Steps in Reading a Micrometer

Reading Micrometers with Vernier Scales

In cases where a measurement must be within 0.0001 inch (one ten-thousandth of an inch), a micrometer with a vernier scale should be used. This micrometer is read in the same way as a standard micrometer. However, in addition to the three scales found on the typical micrometer, this type has a vernier scale on the sleeve. When taking measurements with this mike, read it in the same way as you would a standard mike. Then, find the thimble mark that lines up precisely with one of the vernier scale lines (Fig. 29). Only one of these lines will match up correctly. All other lines will be mismatched. The vernier scale number that matches up with a thimble mark is the 0.0001-inch (one ten-thousandth of an inch) measurement.

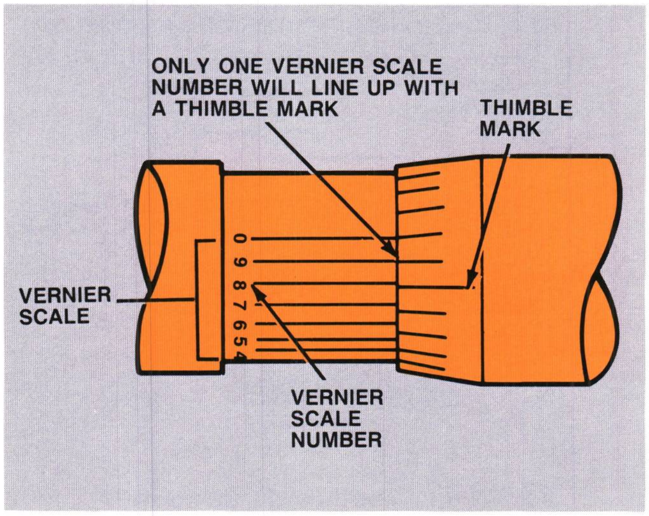

ONLY ONE VERNIER SCALE NUMBER WILL LINE UP WITH A THIMBLE MARK
THIMBLE MARK
VERNIER SCALE
0 9 8 7 6 5 4
VERNIER SCALE NUMBER

Figure 29 — Measuring Ten Thousandths of an Inch Using a Micrometer With Vernier Scale

Reading Metric Micrometers

The metric micrometer is used and read in the same way as a standard (inch-graduated) micrometer, except that the graduations are metric. Therefore, the markings on the metric micrometer have different values than the markings on an inch-graduated micrometer. Refer to Figure 30.

With a metric micrometer, each sleeve number on the sleeve long line represents five millimeters (5mm). There are ten equally spaced lines between the sleeve numbers; these are the sleeve marks. Each sleeve mark represents five-tenths of a millimeter (0.5mm). One complete turn of the thimble moves the spindle five-tenths of a millimeter (0.5mm). The edge of the thimble is marked with 50 equal divisions, called thimble marks. Every fifth thimble mark is numbered. Each of the thimble marks represents one-hundredth of a millimeter (0.01mm).

To read the metric micrometer, first read the number of the sleeve numbers visible on the sleeve long line. Next, count the number of sleeve marks past the sleeve number. Then, count the number of thimble marks past the sleeve marks. Finally, add all the sleeve and thimble readings together to determine the measurement.

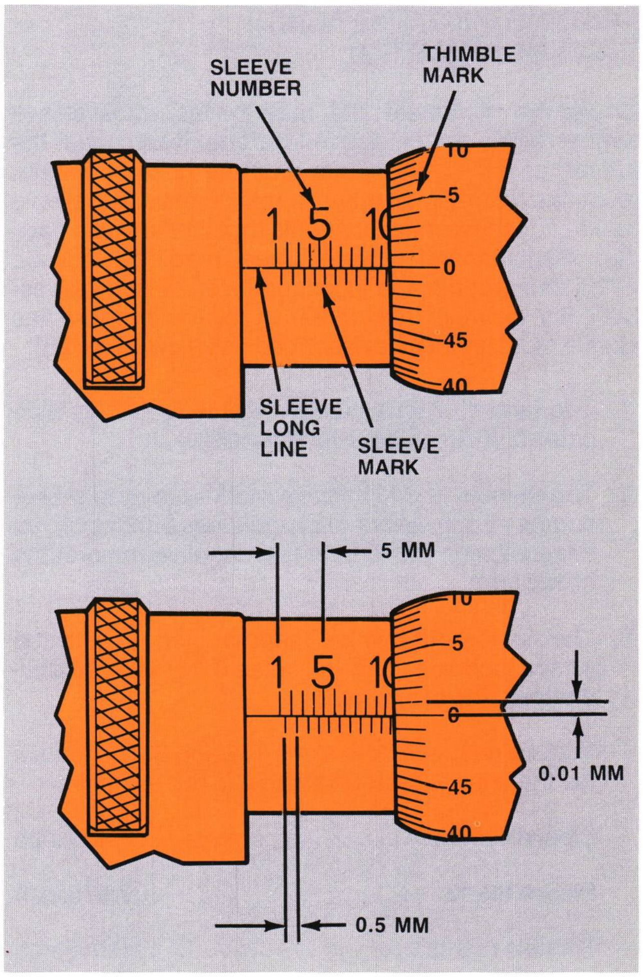


Figure 30 — Metric Micrometer Markings and Graduations

Using Outside Micrometers

To measure small objects using the outside micrometer, grasp the micrometer with your right hand and slip the object to be measured between the spindle and anvil. While holding the object against the anvil, turn the thimble using your thumb and forefinger until the spindle contacts the object. Never clamp the micrometer tight. Use only enough pressure on the thimble to allow the work to just fit between the anvil and spindle. If the micrometer is equipped with a ratchet screw, use it to tighten the micrometer around the object for final adjustment. For a correct measurement, the object must slip through the micrometer with only a very light resistance.

When you are satisfied with the setting, read the micrometer. Be careful not to change the setting.

To measure longer objects (pistons, etc.) hold the frame of the micrometer and slip it over the work while adjusting the thimble (Fig. 31). It is important to slip the mike back and forth over the work until you feel a very light resistance, while at the same time rocking the mike from side-to-side to make certain the spindle cannot be closed any further (Fig. 32). These steps should be taken with any precision measuring device to ensure correct measurements.

Your measurements should be reliable if the mike is calibrated correctly. To calibrate a micrometer, close the mike over an object of known, exact measurements and use it as a standard. If your reading differs from the standard, then your mike will need adjustment.

Always take good care of your mike. Five tips are:

- Always clean the mike before using it.
- Do not touch measuring surfaces.
- Store the mike properly. The spindle face should not touch the anvil face, or a change in temperature might spring the mike.
- Clean the mike after using it. Wipe the mike clean of any oil, dirt, or dust using a lint-free cloth.
- Do not drop the mike. It is a sensitive instrument and must be handled with care.

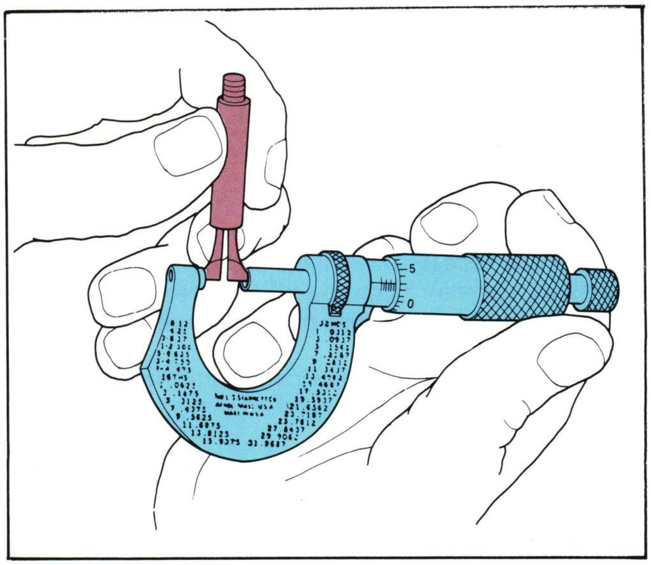


Figure 31 — The Correct Way to Hold an Outside Micrometer When Measuring Small Objects

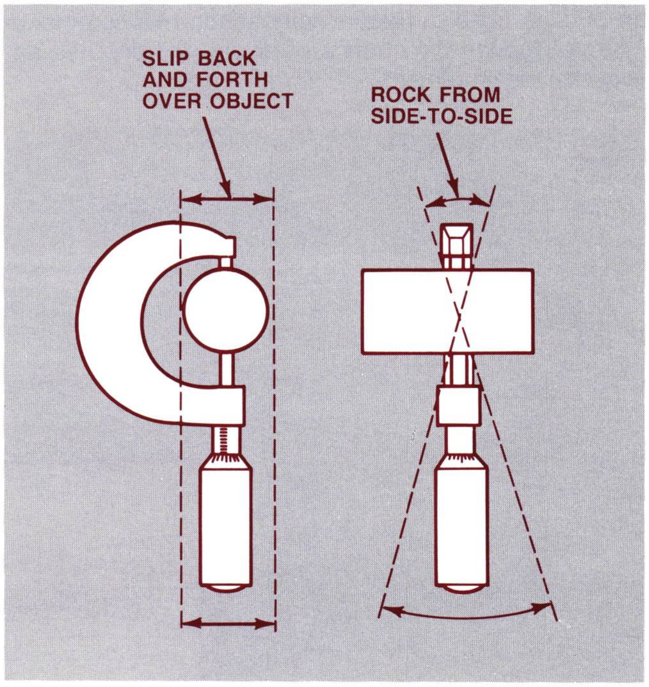


Figure 32 — Slip the Mike

INSIDE MICROMETER

Inside mikes are used to measure bore or hole sizes (cylinder bore etc.). They are frequently used with outside mikes to reduce the chance of error.

To use an inside mike, place it inside the bore or hole and extend the measuring surfaces until each end touches the bore's surface (Fig. 33). If the bore is large, it may be necessary to use an extension rod to increase the mike's range. These extension rods come in various lengths.

The inside micrometer is read in the same manner as an outside micrometer.

To obtain a precise measurement, keep the anvil firmly against one side of the bore and rock the inside mike back and forth and side-to-side (Fig. 34). This ensures that the mike fits in the center of the work with the correct amount of resistance. As with the outside micrometer, this procedure will require a little practice until you get the feel for the correct resistance and fit of the mike.

After taking the measurement with the inside mike, use an outside mike to take a comparison measurement. This will reduce the chance of errors and ensures an accurate measurement.

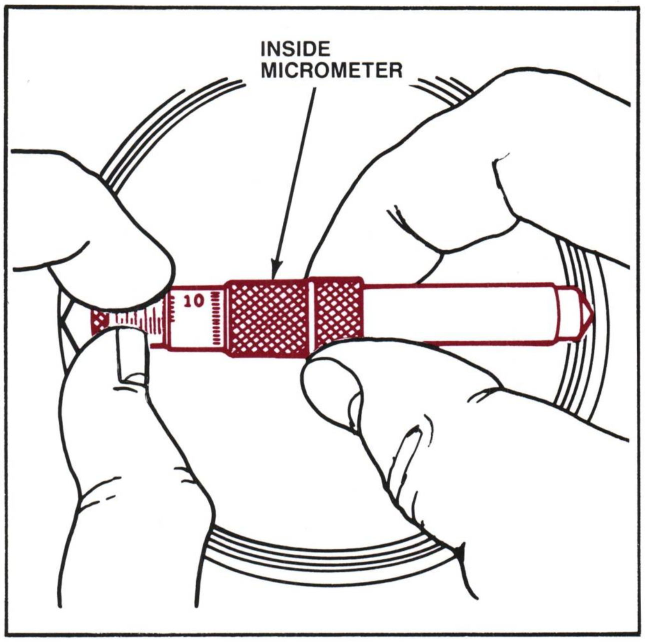


Figure 33 — Measuring with an Inside Micrometer

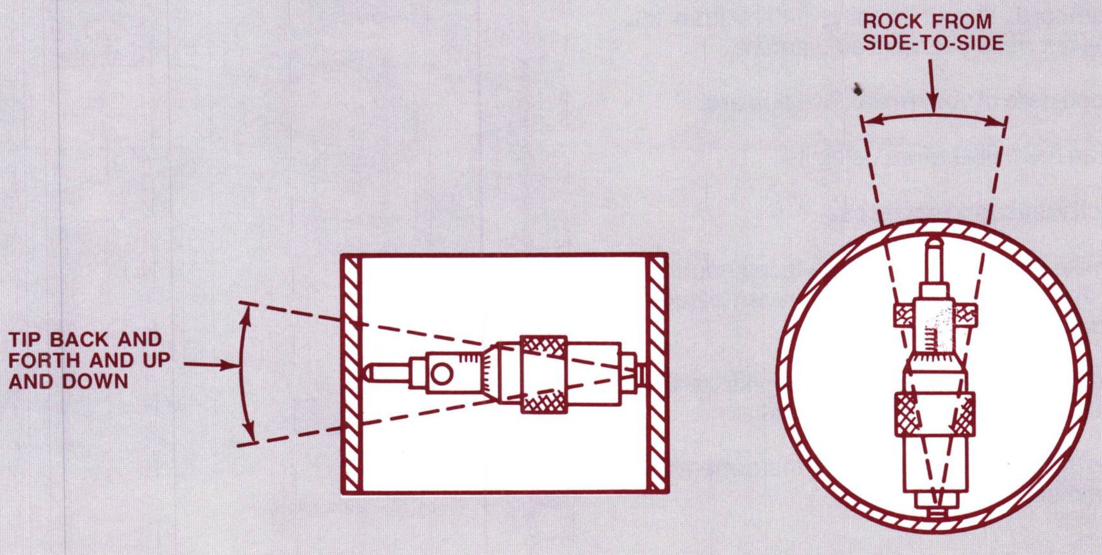


Figure 34 — Tipping and Rocking an Inside Micrometer for Precise Measurements

DEPTH MICROMETER

The depth micrometer (Fig. 35) is used to measure the distance between two parallel surfaces. It is commonly used to measure various end play specifications in transmissions. Depth micrometers are available in inch-graduated and metric models. The sleeves, thimbles and ratchet screws operate in the same manner as the previously described inside and outside micrometers. Depth mikes are read in the same way as other micrometers.

If the depth micrometer is used with a gauge bar, it is essential to keep both the bar and the micrometer from rocking. Any movement of either part will result in an inaccurate measurement.

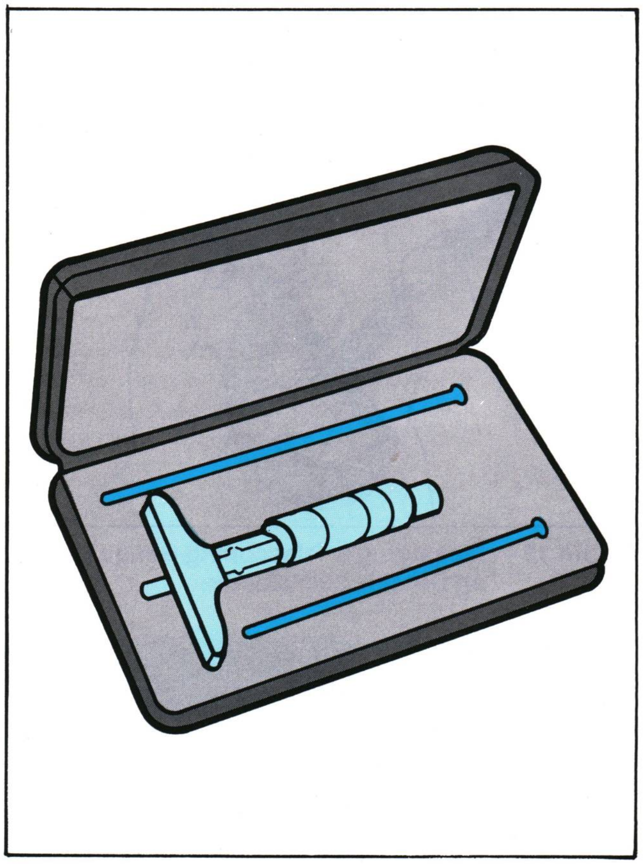


Figure 35 — Typical Depth Micrometer—0-3 Inch Range in 0.001-Inch Graduations

Measuring End Play (Typical)

To measure end play at the reverse clutch drum thrust face (typical automatic transmission) perform the following procedure:

1. Set an end play gauge bar across the pump case mounting flange.
2. Position the depth micrometer onto the gauge bar so that the micrometer spindle bears on the reverse clutch drum thrust face (Fig. 36).
3. Read and record the value indicated on the Micrometer.
4. Obtain a second reading 180 degrees opposite the place where the first reading was taken. Add the two readings together and divide by two in order to obtain the average depth.

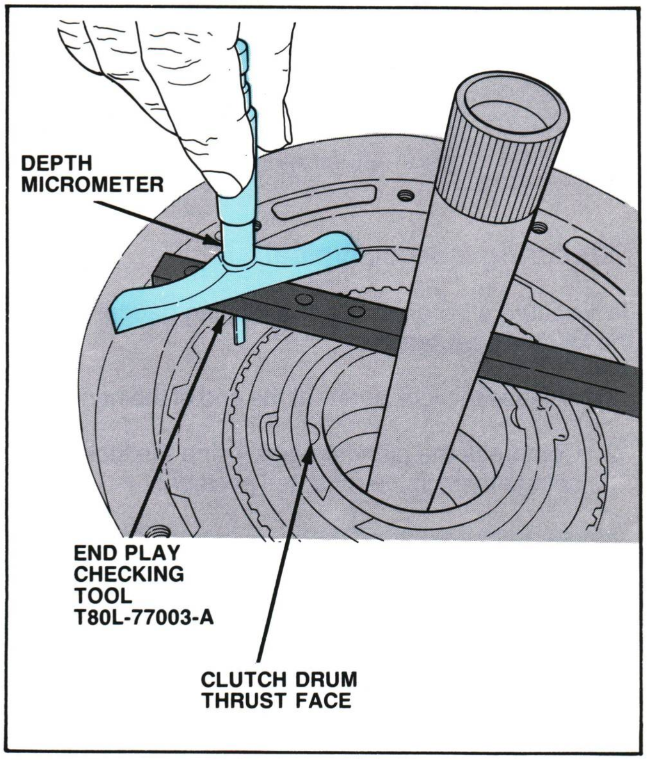


Figure 36 — Gauging Reverse Clutch Drum End Play Using a Depth Micrometer

TELESCOPING GAUGES

Telescoping gauges (Fig. 37) are used for measuring bore diameters and other clearances. They are normally offered in sizes ranging from fractions of an inch through six inches. Each gauge consists of two telescoping plungers, a handle and a lock screw. Telescoping gauges are usually used with an outside micrometer. The gauge is first expanded within the work. Then, the telescoping gauge is measured using the micrometer.

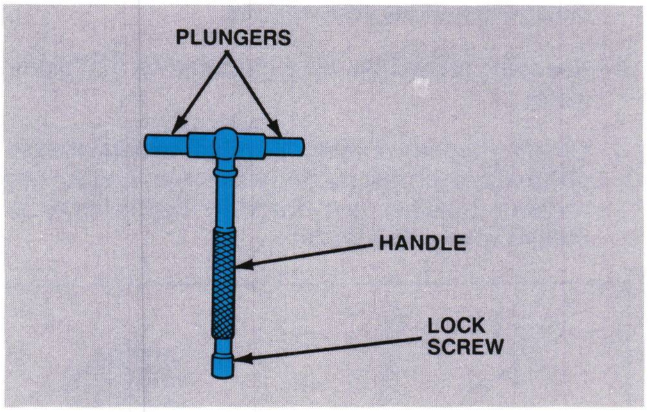


Figure 37 — Typical Telescoping Gauge

Measuring a Bore (Typical)

To measure a bore using a telescoping gauge, perform the following procedure:

1. Release the lock screw at the end of the handle.
2. Compress the plungers and, using the lock screw, secure them in the retracted position.
3. Place the telescoping gauge into the bore (Fig. 38). Release the plungers by loosening the lock screw. Allow the plungers to expand until they contact the bore walls.
4. Rock the telescoping gauge back and forth and side-to-side to check for the correct resistance (Fig. 38). These motions are similar to the method used to center a micrometer on the work.
5. When you feel the correct resistance, lock the plungers into position using the lock screw. Then, carefully retract the telescoping gauge from the bore.
6. To complete the measurement, use an outside micrometer to determine the distance between the two plunger faces (Fig. 39). Measuring the distance between the extended plungers is the same as measuring the bore.

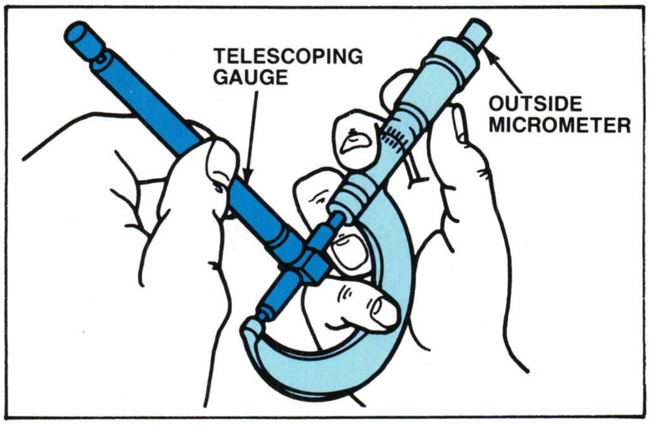


Figure 39 — Measuring a Telescoping Gauge Using an Outside Micrometer

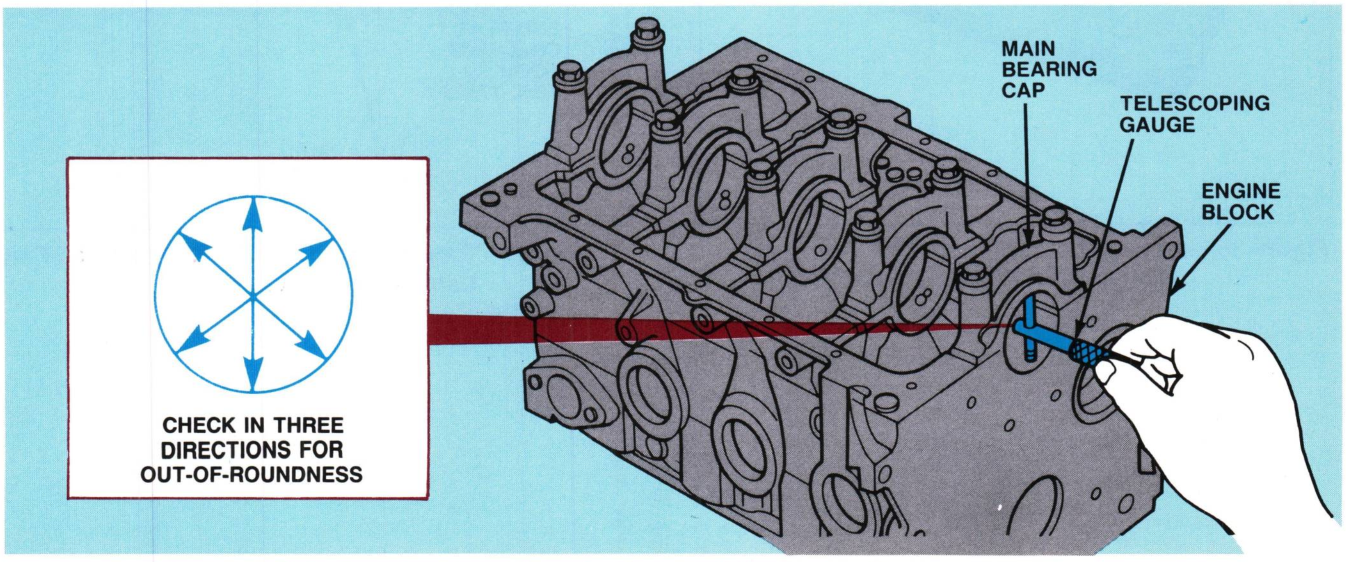


Figure 38 — Checking Main Bearing Bore Diameter Using a Telescoping Gauge

SMALL HOLE GAUGE

The small hole gauge functions in the same manner as the telescoping gauge. It is expanded in a bore, and then measured with an outside micrometer (Fig. 40). Like the telescoping gauge, the small hole gauge consists of a lock, handle and an expanding end. The small hole gauge is commonly used to determine the diameter of valve guides.

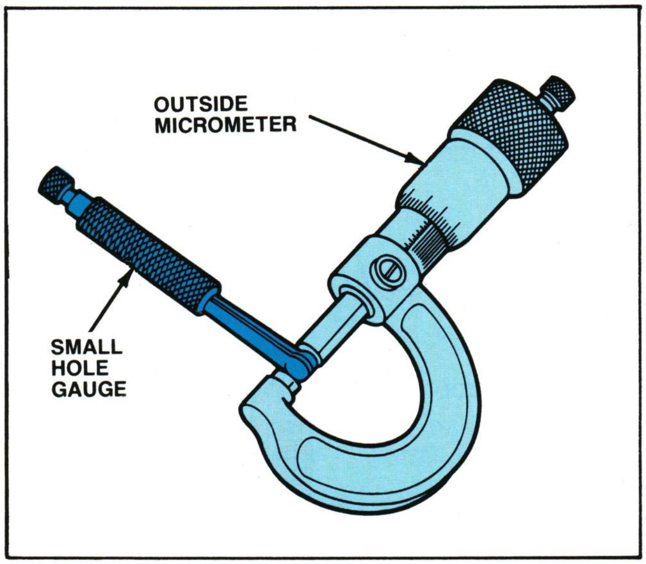


Figure 40 — Measuring a Small Hole Gauge Using an Outside Micrometer

Measuring Valve Guide Diameter (Typical)

To measure valve guide diameter, perform the following procedure (Fig. 41):

1. Insert the small hole gauge into the valve guide.
2. Allow the gauge to expand until it contacts the valve guide bore walls.
3. Rock the gauge from side-to-side to center it in the valve guide. This motion is similar to the method which is used to center telescoping gauges and micrometers on the work.
4. When the correct resistance is felt, lock the gauge into that position and carefully withdraw it from the valve guide.
5. Measure the small hole gauge with an outside micrometer.
6. Repeat this procedure at the top, middle and bottom of the guide to determine overall wear. Because valve guides wear more at the ends than in the middle, it is not unusual to obtain a different reading in the middle of the guide.
7. If you wish to determine stem-to-guide wear, measure the valve stem using an outside micrometer and subtract stem diameter from the three valve guide readings. The resulting figure equals valve stem-to-guide clearance.

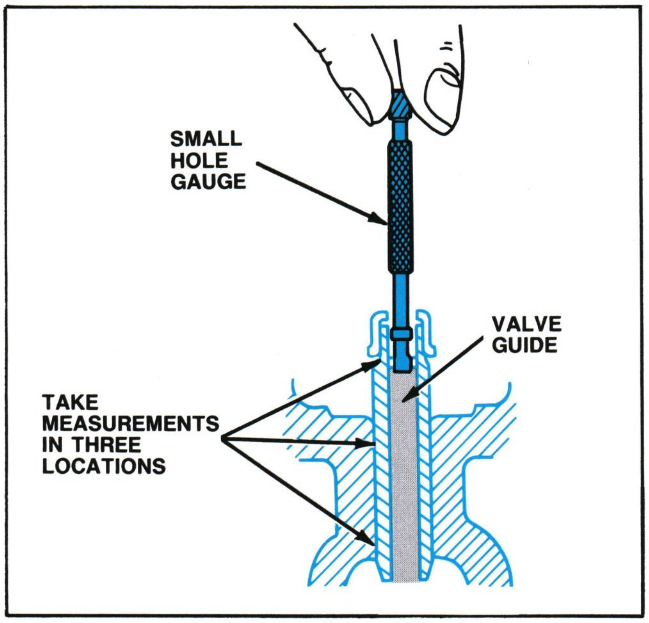


Figure 41 — Measuring Valve Guide Diameter with a Small Hole Gauge

PINION ANGLE LEVEL GAUGE

The pinion angle level gauge is used to determine the driveshaft/pinion angle (Fig. 42) in order to minimize driveline wear and noise. This gauge consists of a magnet, arm, level gauge and adjusting screw.

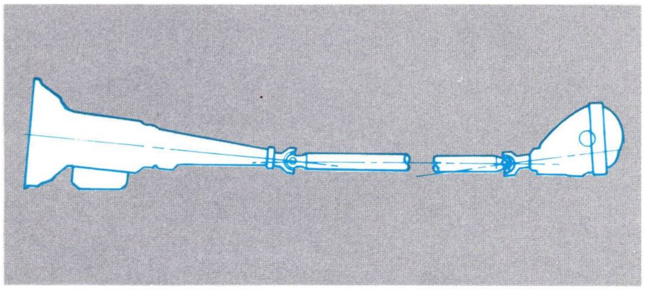


Figure 42 — Driveline Angles

Measuring Pinion Angle (Typical)

To determine pinion angle, perform the following procedure:

1. Apply a load sufficient to attain the curb height specified in the applicable pinion angle chart. If necessary, refer to the applicable service publication for specifications.
2. Position the V-magnet portion of the pinion angle level gauge onto the driveshaft (Fig. 43). Do not position the magnet onto any welds or balance weights.
3. From the LH side of the vehicle, position the pinion angle level gauge onto the V-magnet with the adjusting screw facing to the left. Adjust the dial on the tool until the LH edge of the bubble is exactly on the zero line.
4. Position the magnetized tool onto a U-joint bearing cap with the tool in the same relative position that it was in when it was attached to the V-magnet (Fig. 44).
5. Read and record the position of the LH edge of the bubble. Driveshaft pinion angle is indicated on the scale by the position of the LH edge of the bubble.

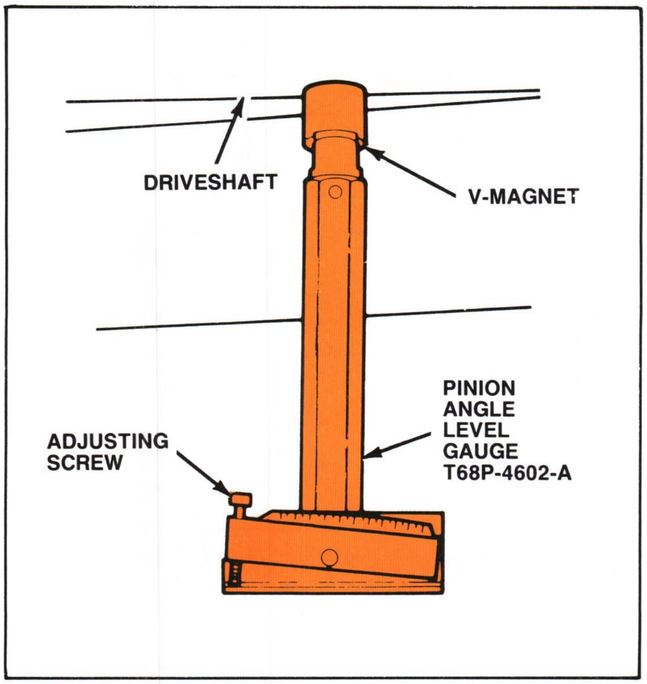


Figure 43 — Positioning Tool Onto V-Magnet

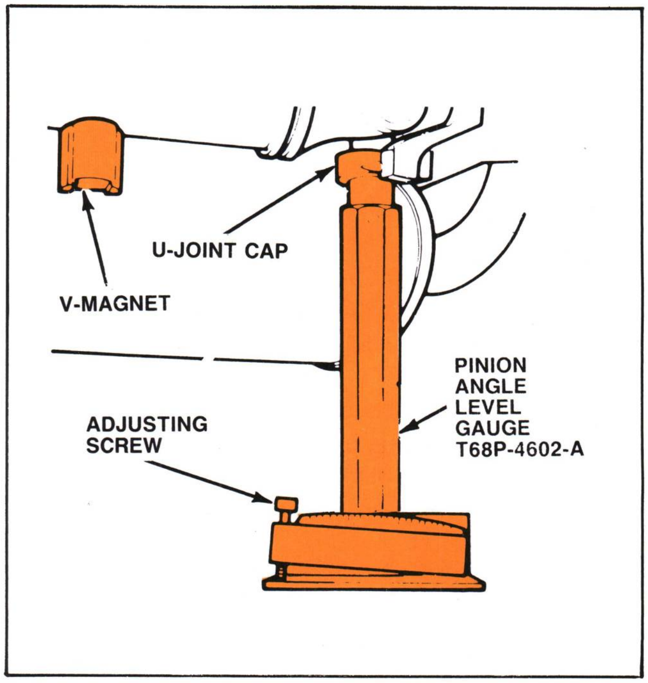


Figure 44 — Pinion Angle Measurement

ELECTRICAL MEASURING DEVICES

Electrical measuring devices are used to check the operation of electrical components and circuits. These devices are capable of very accurate measurements. However, in order to get an accurate measurement with an electrical instrument, you must be able to connect, calibrate, read and interpret the information provided by the instrument.

Electrical instrument calibration, reading and interpretation will be covered in detail later in this publication. For now, we will concern ourselves with the safe connection and use of electrical measuring devices. When using electrical instruments, always observe the following rules:

- Always route your electrical test leads so that they are well clear of the coolant fan, accessory drive belts, hot manifolds or other components which might damage them. A wire clothes hanger or welding rod bent into an S-shape and hooked into a convenient position can keep test leads out of trouble.
- Make sure that the ignition switch is off until you are ready to perform your test.
- Make sure that you properly connect the test leads to the negative and positive points of the circuit. The necessity of proper connection is referred to as polarity. If the test instrument leads are connected improperly, the test instrument and/or the component may be damaged, or you may get an incorrect reading.
- Never position a test instrument where it might fall or strike other tools.
- Always connect a voltmeter ACROSS a component. Do not connect the voltmeter into the circuit.
- Always connect an ammeter INTO a circuit. Do not connect an ammeter across a component. If you "bridge" the component with the ammeter, you create a current path which may result in damage.
- Make sure that the ammeter is rated to carry more current than is present in the circuit you are testing.
- Never use a high resistance test instrument when you are working on sensitive circuits.
- Always use the calibrated test leads which are included with the meter.
- Never connect an ohmmeter into a live circuit. Always disconnect the power or remove the component prior to testing it.
- Always zero the meter prior to performing any tests.
- If your ohmmeter delivers erratic readings, replace the internal battery before continuing your test procedure.

NOTE: Check your instruments regularly against known good equipment to ensure that they are operating properly and capable of accurate measurement.

NOTE: Always refer to the appropriate shop manual or reference material for the correct specifications before performing service or diagnosis procedures. The close tolerances in current vehicles makes using the correct specification and accurate measurements more important than ever.

TEST LAMP — CIRCUIT-POWERED

The circuit-powered test lamp consists of a bulb connected between a test lead and a probe tip. The automotive type is commonly referred to as a 12-volt test lamp because almost all automotive electrical systems operate on 12 volts DC.

The 12-volt test lamp depends upon the vehicle's battery to power the circuit which is being tested. These testers are equipped with a variety of tips to allow them to be used in all types of test situations (Fig. 45).

Test lamps do not measure voltage in terms of "how much." What they indicate is whether or not voltage is present in a circuit. Thus, test lamps are useful when you are testing for an open circuit.

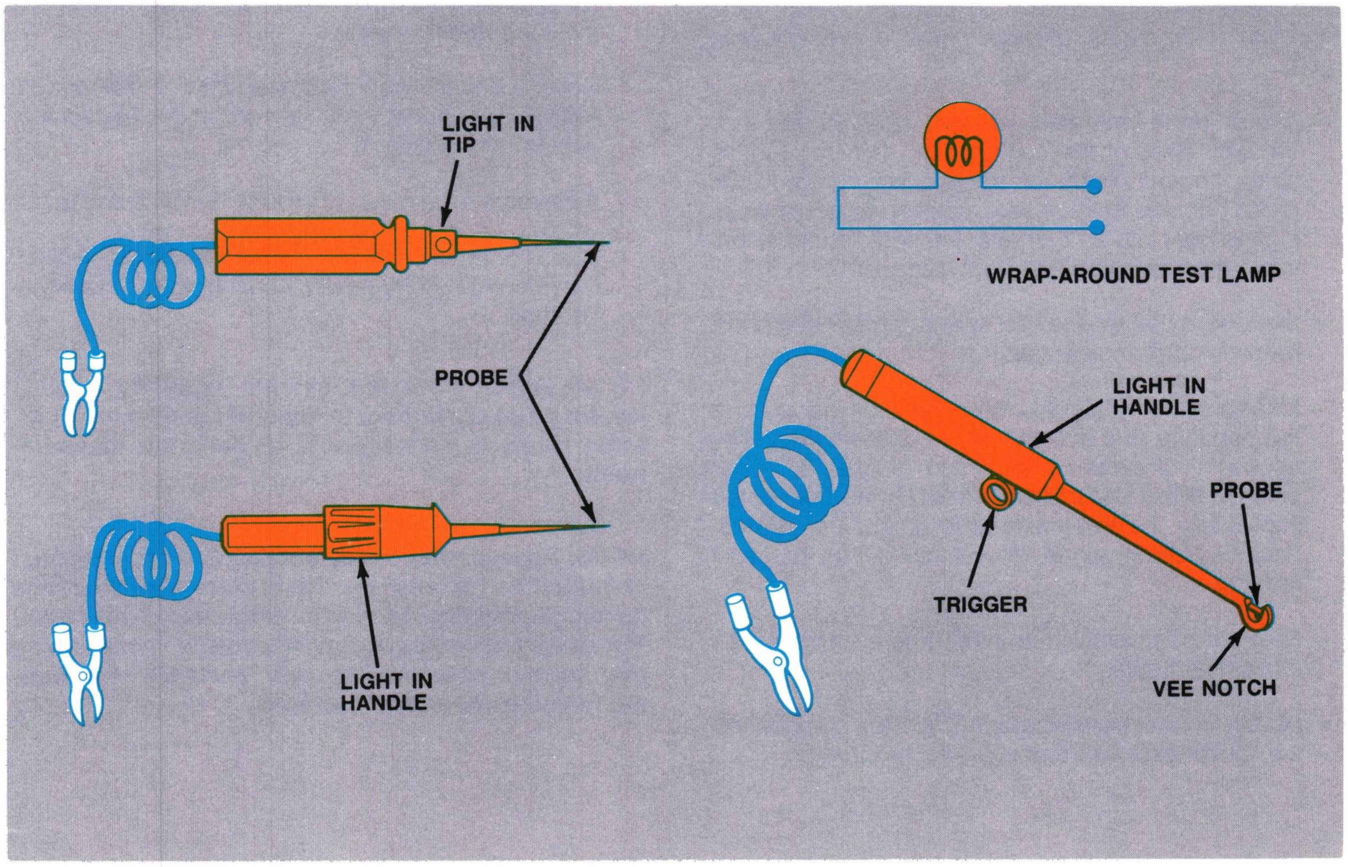


Figure 45 — Types of Circuit-Powered Test Lamps

Checking a Circuit

To use the circuit-powered test lamp, perform the following procedure:

1. Check test lamp operation by connecting it across the battery terminals. If the lamp lights, it is in working order.
2. Clip the test lead to any known good ground. The ground may be tested by connecting 12 volts to the probe tip with a jumper wire.
3. Touch the probe tip to any test point at which voltage should be present (Fig. 46).
4. If the lamp lights, voltage is present at the test point. If the lamp does not light, the circuit is open.
5. If the test lamp lights but is dim, a high resistance condition exists between the voltage source and the test point.
6. The probe tip can be used to pierce insulation when checking for voltage (Fig. 47). Keep the probe tip sharp so that it makes a small hole in the insulation. After piercing a wire, cover the hole with electrical tape to prevent water or corrosion from causing a short to ground.

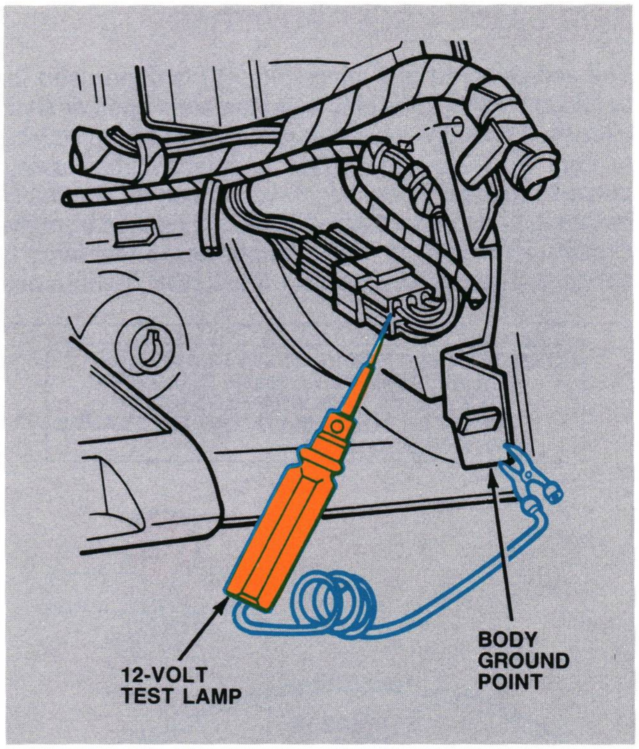


Figure 47 — Back-Probing a Harness Connector Using a 12-Volt Test Lamp

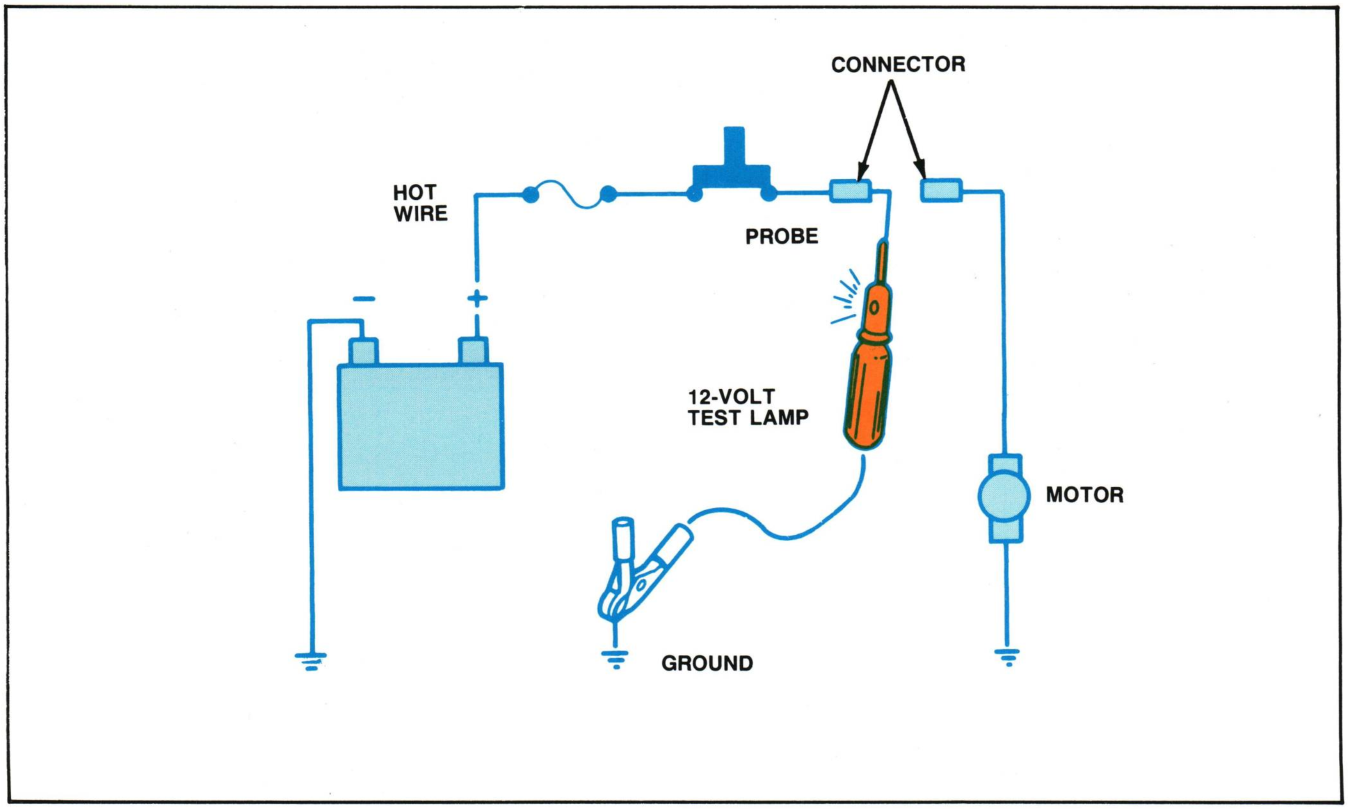


Figure 46 — Using the Circuit-Powered Test Lamp

TEST LAMP — SELF-POWERED

The self-powered test lamp (Fig. 48) is often used for continuity testing. It is also used to detect open or short circuits. It contains a battery which provides the voltage to light the test lamp when a closed circuit exists between the test leads. When you check for continuity, isolate the component which is being checked from the circuits connected to it. If a self-powered test lamp is connected across 12 volts, its 1.5-volt bulb will burn out.

NOTE: THE SELF POWERED TEST LAMP MAY CAUSE DAMAGE TO SOME ELECTRICAL DEVICES BY APPLYING EXCESSIVE VOLTAGE TO THEM VIA THE TEST LAMPS POWER (BATTERY).

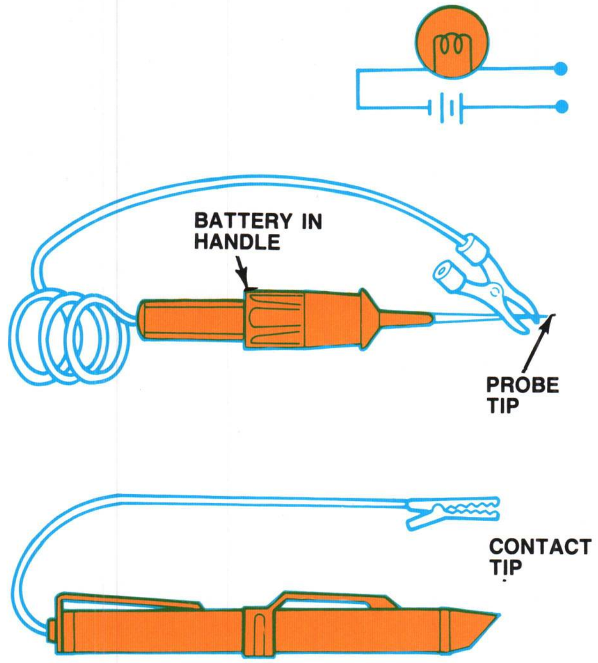


Figure 48 — Typical Self-Powered Test Lamps

Before you perform any continuity tests, verify that the tester is in good working order. Check the tester by connecting the test lead clip to the probe tip. If the lamp lights, the tester is okay. If the lamp does not light, check the bulb, battery and internal contacts. Keep the contacts clean and the battery fresh to ensure proper test lamp operation.

Continuity Testing (Typical)

To test for continuity between two points, perform the following procedure (Fig. 49):

1. Clip the test lead to one point of the component being tested.
2. Touch the probe/contact tip to the other point being tested.
3. If the lamp lights, continuity exists between the two points.
4. If the lamp does not light, no continuity exists between the two points.

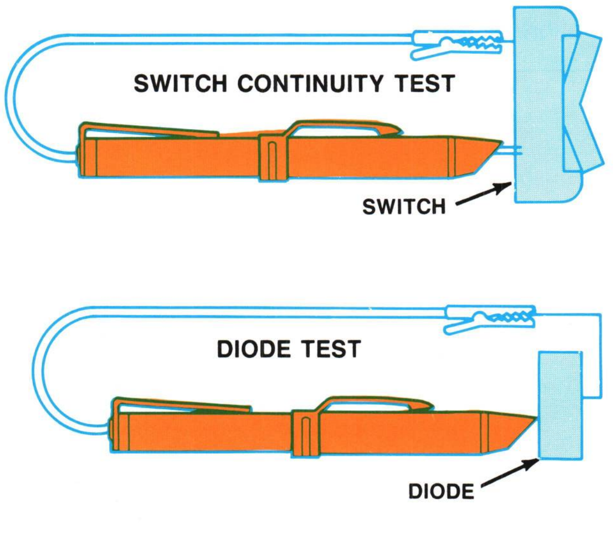


Figure 49 — Testing For Continuity Between Two Points

Testing for a Short Circuit

To test for a short to ground in the "hot" circuit using a self-powered test lamp, perform the following procedure (Fig. 50):

1. Turn the switch off.
2. Remove the fuse.
3. Connect the test lamp from the fuse terminal **to the load.**
4. Ground the contact or probe tip.
5. Turn the switch on. If the lamp lights, the hot circuit is grounded.

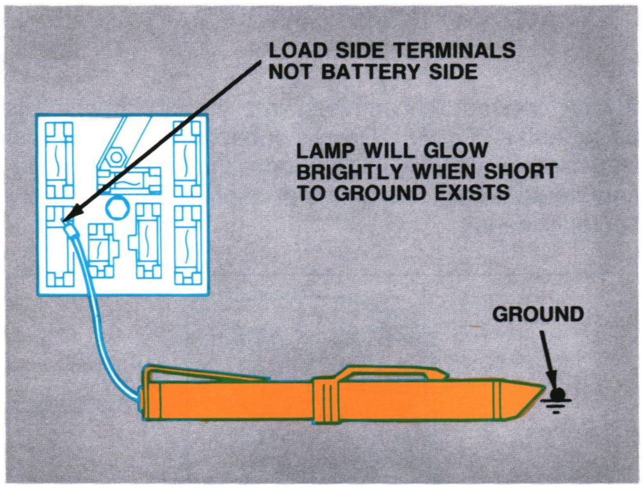


Figure 50 — Testing for a Short to Ground in the Hot Circuit

ANALOG VOLTMETER

The voltmeter measures voltage. It usually incorporates several range settings which allow it to adjust to various measurement conditions. It is equipped with positive (usually red) and negative (usually black) test leads. The test leads have polarity; the leads must be properly connected to the positive and negative points of a circuit. Additionally, the voltmeter must always be connected across a component. It must never be inserted into a circuit. Voltmeters are available in either analog (with an indicator needle and gauge), or digital models. Digital meters will be discussed separately.

The voltmeter is an essential electrical diagnosis tool. You can use it to measure and compare expected voltage values with actual circuit voltages. This method of diagnosis is referred to as voltage drop. The voltage present at any point in the circuit is referred to as available voltage.

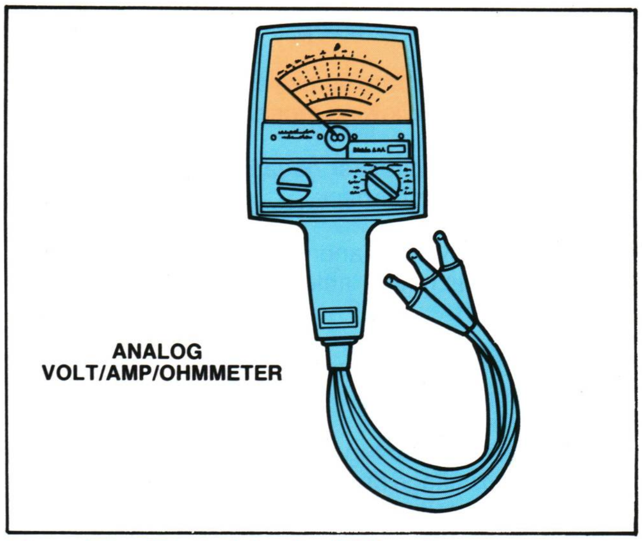


Figure 51 — Typical Analog Voltmeter

Measuring Available Voltage (Typical)

To measure available voltage with the voltmeter, perform the following procedure (Fig. 52):

1. Select a voltmeter operating range that is higher than the voltage being measured.
2. Ground the negative voltmeter lead at any convenient point on the vehicle.
3. Touch the positive voltmeter lead to any point in the circuit where you want to read voltage. Available voltage will be indicated on the voltmeter gauge face.

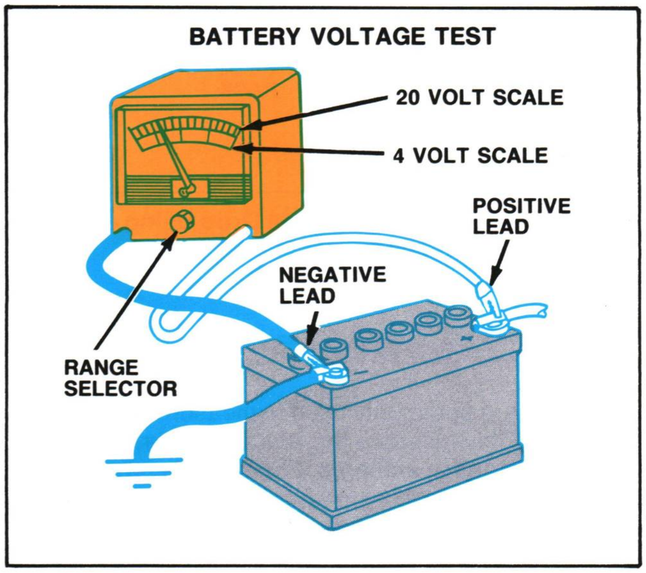


Figure 52 — Measuring Available Battery Voltage Using a Voltmeter

Measuring Voltage Drop

To measure voltage drop across a heater blower resistor pack, perform the following procedure (Fig. 53):

1. Connect the voltmeter negative lead to the ground side of the resistor pack.
2. Turn the blower on and make sure that it is operating. You will not be able to obtain a reading if the circuit is off.
3. Touch the voltmeter positive lead to the hot side of the component.
4. Compare the voltage reading obtained with the specified voltage drop value. A voltage drop greater than the specified value usually indicates excessive resistance somewhere in the circuit.

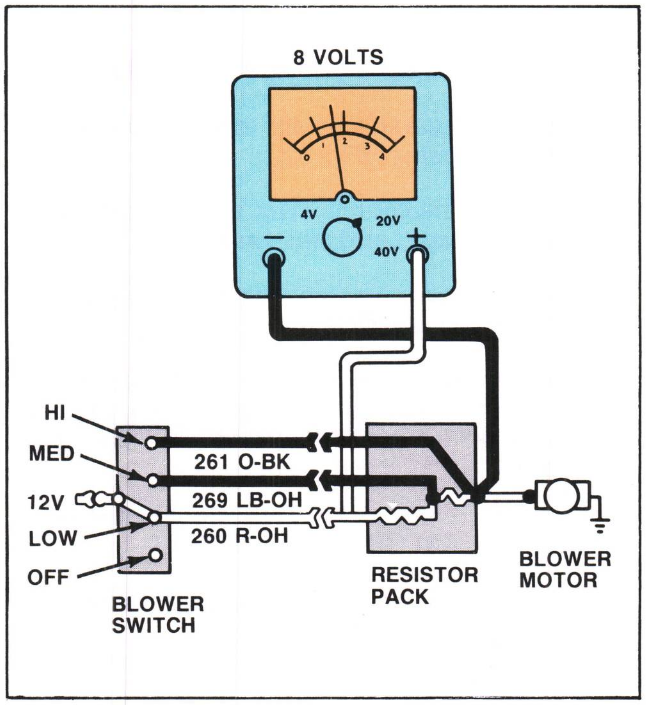


Figure 53 — Measuring Voltage Drop Using a Voltmeter

ANALOG AMMETER

Ammeters are commonly used to measure current draw or output. They measure the amount of current flowing through a circuit in amperes. For example, an ammeter is the instrument which you would use to determine alternator output. Ammeters are commonly used to measure blower motor current draw. Current draw readings are compared to specifications to determine whether the blower motor is in satisfactory operating condition.

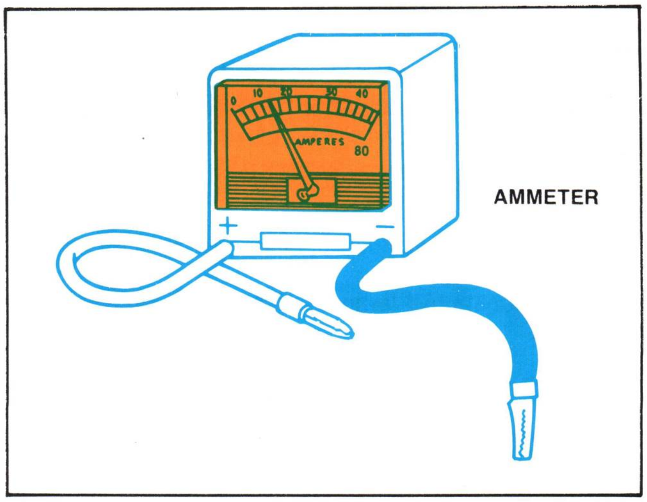


Figure 54 — Typical Analog Ammeter

Always connect the ammeter into the circuit which is being tested (Fig. 55). Never connect the ammeter test leads across a circuit, or damage to the meter or component could result. The ammeter should always be connected in series.

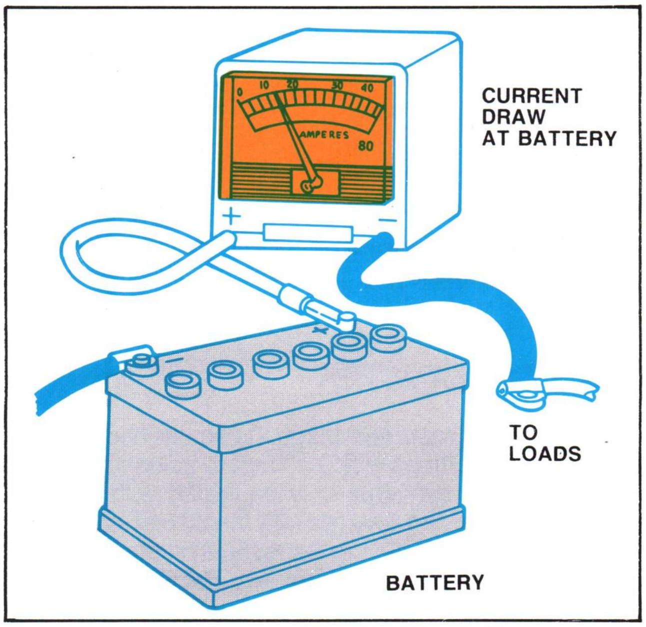


Figure 55 — Measuring Current Draw at Battery with Ammeter

Ammeter test leads, like other test instruments, have polarity; they must be properly connected to the negative and positive points of a circuit. The positive (usually red) lead should be connected to the positive side of the circuit (Fig. 55). The negative (usually black) lead should be connected to the load side of a circuit (Fig. 55).

Checking Blower Motor Current Draw (Typical)

To measure blower motor current draw using the ammeter, perform the following procedure (Fig. 56):

1. Turn the blower switch off.
2. Observing correct test lead polarity, clip the ammeter leads into the circuit.
3. Turn the blower switch on and note the meter reading (current).
4. If the blower switch is the multiple position type, take a reading in each switch position (Example: OFF, 1, 2, 3, HIGH).
5. Turn the blower switch off, disconnect the ammeter, and restore the original circuit connection.
6. If you get a reading of zero amps, either the circuit is open or the power is not on.
7. If you get a current draw reading higher than specifications, a short circuit to ground or a short which bypasses the load exists.
8. If you get a current draw reading which is lower than specifications, there is either too much resistance in the system or a low available voltage condition exists.

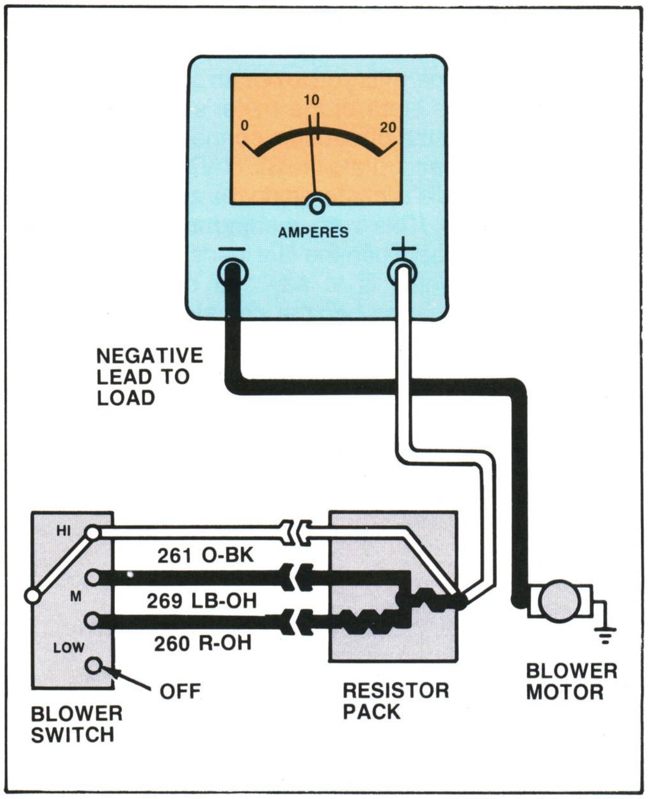


Figure 56 — Checking Blower Motor Current Draw

ANALOG OHMMETER

The ohmmeter (Fig. 57) measures a circuit's resistance to current flow in ohms (Ω). It operates on a known voltage supplied from an internal battery. It is commonly used to measure ignition coil resistance, secondary ignition wire resistance and all types of semiconductor resistances. Like all precision test equipment, the ohmmeter should be regularly checked against known good equipment to ensure accuracy.

NOTE: Never connect the ohmmeter to a circuit in which voltage is present (hot) or meter damage could occur. The ohmmeter operates on an internal low voltage source.

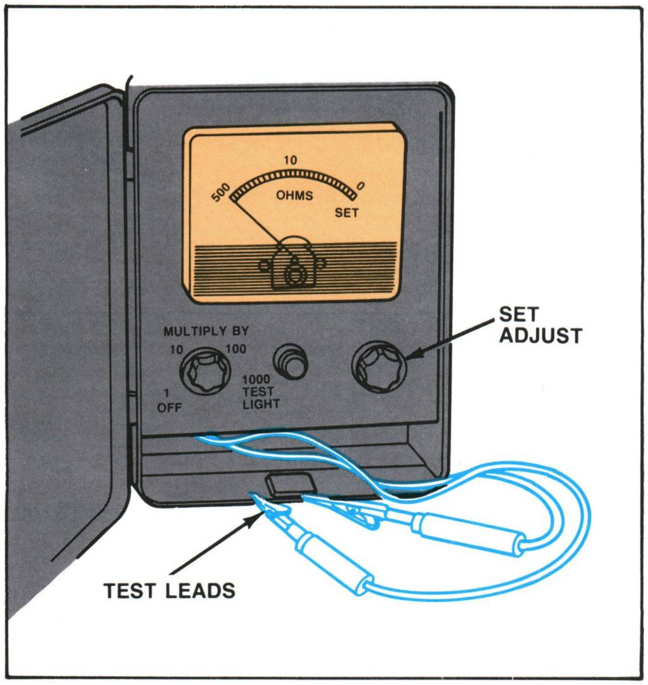


Figure 57 — Typical Analog Ohmmeter

Before you measure resistance with an ohmmeter, you must "zero" it. This adjustment allows for variations in battery charge. It permits you to obtain an accurate reading as the charge state of the meter's internal battery changes. To zero the ohmmeter, connect the test leads together (Fig. 58) and rotate the SET/ADJUST knob until the indicator needle is centered on the zero at the beginning of the scale. This zero reading indicates that no resistance exists between the test leads. Another way to interpret this reading is to say that continuity exists between the test leads when the indicator needle moves fully across the scale and points at zero.

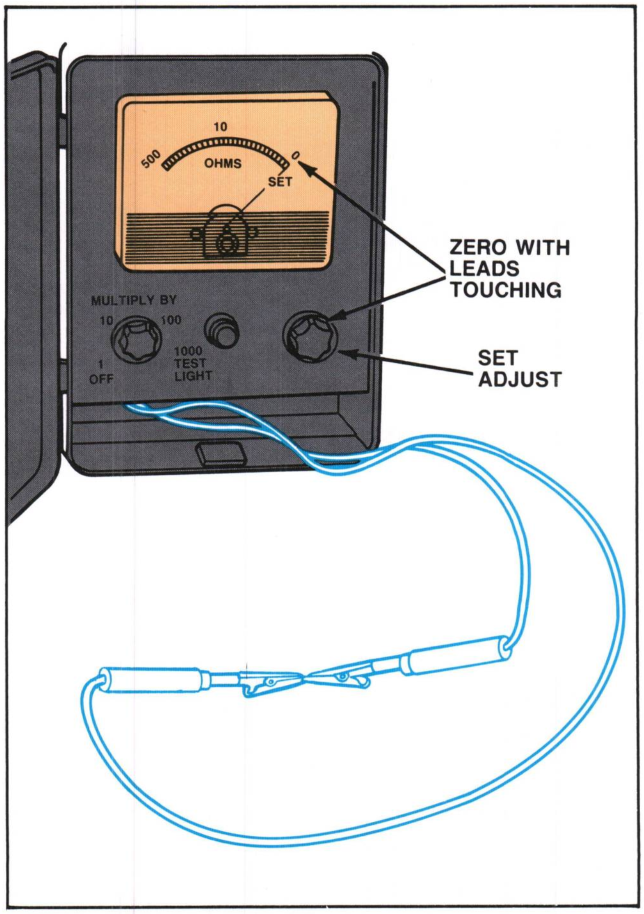


Figure 58 — Zeroing the Ohmmeter

Checking Circuit Resistance (Typical)

To measure resistance using an ohmmeter, perform the following procedure (Fig. 59):

1. Disconnect the load (or the component to be tested) from the circuit.
2. Choose a multiplier scale which corresponds to the expected circuit resistance.
3. Clip the test leads together and turn the SET/ADJUST control until the indicator needle is centered on zero.
4. Touch the leads to the terminals of the circuit to be tested.
5. It is not necessary to observe test lead polarity if the circuit is open.
6. To obtain the resistance of the circuit, multiply the reading on the scale by the setting on the multiplier scale.
7. If the meter reads zero, continuity (no resistance) exists in the circuit.
8. If the indicator needle does not deflect, the circuit is open (infinite resistance).

Reading X Multiplier Scale = Resistance

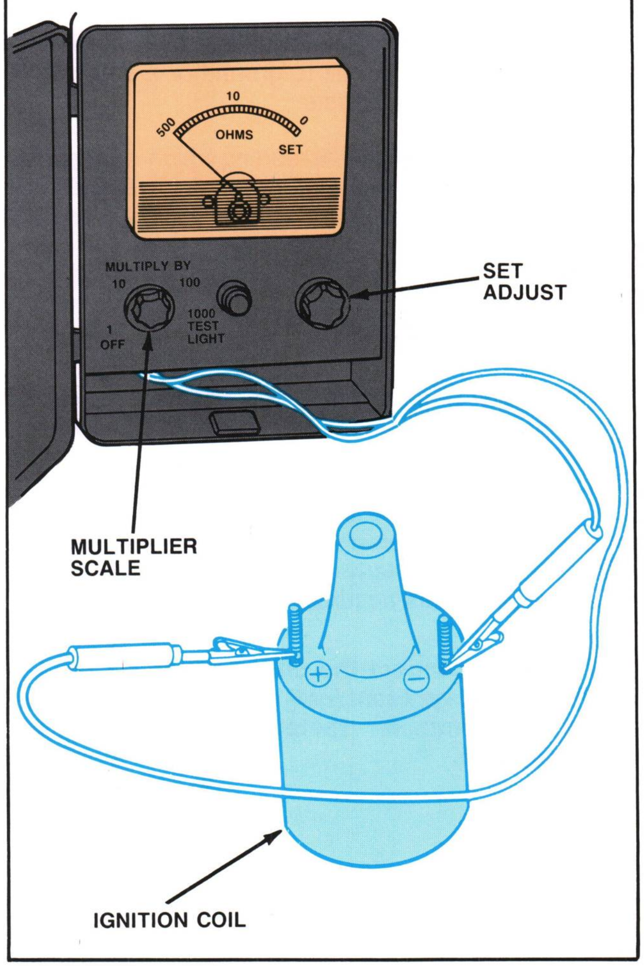


Figure 59 — Measuring Resistance With an Ohmmeter

DIGITAL VOLT/OHMMETER

Digital Volt/Ohmmeter (DVOM) (Fig. 60) use is similar to analog voltmeter and ohmmeter use. The digital meter differs from the analog meters primarily in the way that it displays information. Like the analog meters, the DVOM incorporates several operating ranges which measure various voltages and resistances. Some digital volt/ohmmeters can be connected to other testing equipment. Refer to the usage instructions included with the test equipment for additional information.

The DVOM is equipped with a negative (usually black) test lead and a positive (usually red) test lead. These test leads have polarity; they must be properly connected to the negative and positive points of a circuit. Digital voltmeters often indicate reverse polarity (test leads connected backwards) by displaying a minus (-) sign ahead of the voltage value. Correct polarity is indicated by a positive (+) sign displayed ahead of the voltage value. In the VOLTS DC position the meter will display a reading (usually + 1) indicating that more voltage is present in the circuit than the DVOM is capable of measuring.

NOTE: When the meter is in the VOLTS DC operating mode, never connect the test leads into a circuit. Always ground the negative test lead and probe for the presence of voltage with the positive lead to avoid overloading the meter.

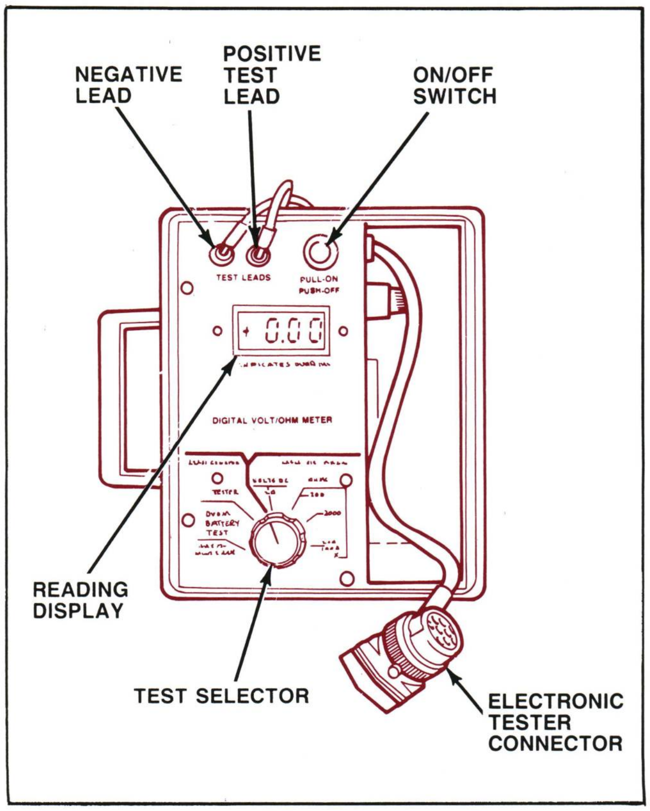


Figure 60 — Typical Digital Volt/Ohmmeter

Most digital volt/ohmmeters include an operating mode which permits internal battery condition to be checked. The meter's internal battery must be in good condition or the DVOM will not display accurate or consistent readings. Like all precision test equipment, the DVOM should be regularly checked against known good equipment to ensure accuracy.

In addition to being able to measure voltage and indicate polarity, the DVOM is able to measure resistance in ohms. Various operating ranges enable resistance to be measured from 0-200,000 ohms. If too low an operating range is selected, the DVOM will display a reading (usually + 1) indicating that you need to select a higher range.

NOTE: With the meter in the OHMS operating mode, never connect the meter to a circuit in which voltage is present or damage to the meter will occur.

When you use the DVOM, you must always note the position of the decimal point in order to obtain a correct reading. Typically, the DVOM OHMS operating mode includes three scales which may be selected individually: 200, 2000, and 200 × 1000. **In most operating positions, the meter reading must be multiplied by the test selector setting to obtain a reading.**

The various ohm scales are used as follows:

The 200 Ohm Scale

The 200 ohm scale is used to check for resistances from 0-199.9 ohms. If a circuit is tested which has a resistance greater than 199.9 ohms, the DVOM will usually display a reading which indicates that circuit resistance exceeds the meter's ability to measure in the present setting. **If such a reading (usually + 1) appears, select the next ohm scale and retest the circuit.**

It is important to pay attention to the position of the decimal point when reading the DVOM in the 200 ohm scale setting. With the test selector in the 200 ohm position, a reading of 155 indicates one hundred and fifty-five ohms of resistance in the circuit. A reading of 15.5 indicates fifteen and one-half ohms of resistance in the circuit.

The 2000 Ohm Scale

The 2000 ohm scale is used to check for resistances from 0-1999 ohms of resistance. If a circuit having a resistance greater than 1999 ohms is tested, the DVOM will usually display a reading which indicates that circuit resistance exceeds the meter's ability to measure in the present setting. **If such a reading (usually + 1) appears, select the next ohm scale and retest the circuit.** With the test selector in the 2000 ohm position, the decimal point is not used.

The 200 x 1000 Ohm Scale

The 200 x 1000 ohm scale is used to check for resistances from 0-199999 ohms of resistance. If a circuit having resistance greater than 199999 ohms is tested, the DVOM will display a reading which indicates that circuit resistance exceeds the meter's ability to measure. This reading is commonly considered to be an open circuit when testing automotive electrical systems.

With the test selector in the 200 × 1000 ohm position, all readings must be multiplied by 1000 to obtain the circuit resistance value. It is important to pay attention to the location of the decimal point to obtain a correct reading in this position. If a reading of 22.0 is displayed, this indicates 22,000 ohms resistance (22.0 × 1000 = 22,000). A reading of 18.5 indicates 18,500 ohms resistance (18.5 × 1000 = 18,500).

DVOM PROVE OUT (TYPICAL)

Two checks must be made prior to checking resistance with the DVOM. The battery and the ohm scale must be checked to ensure accurate readings.

To perform the battery test, turn the DVOM on and place the selector switch in the BATTERY TEST position (Fig. 61). If you obtain a reading less than the specified minimum, replace the DVOM battery with a known good one, and repeat the battery test.

The ohm scale must be checked to be certain that the ohmmeter portion of the DVOM is at zero level with the power switch on. To perform the ohm scale check, place the test selector in the 200 OHMS position (Fig. 62). Clip the test leads together and observe the display. A reading of +00.1 or +00.2 is acceptable; this allows for a small resistance in the test leads. With the test selector in the 2000 OHMS or the 200 × 1000 OHMS position, the display should read 00.0 (Fig. 62).

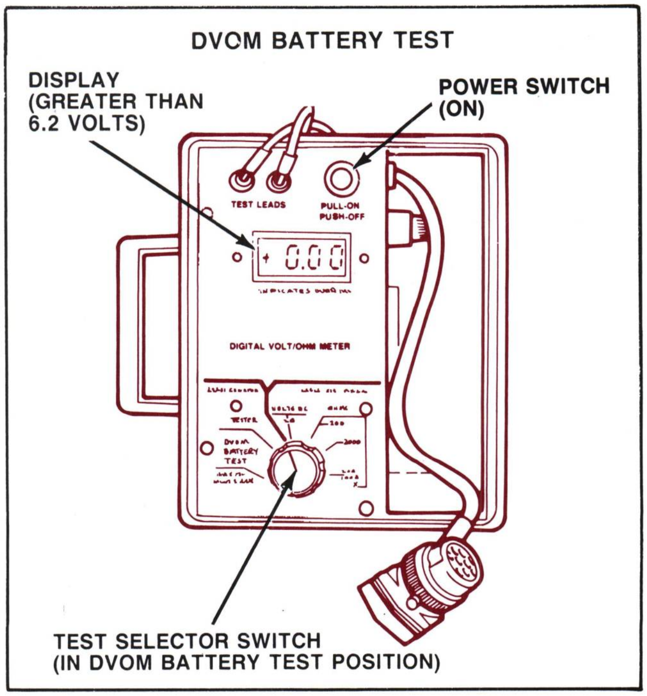


Figure 61 — The DVOM Battery Test

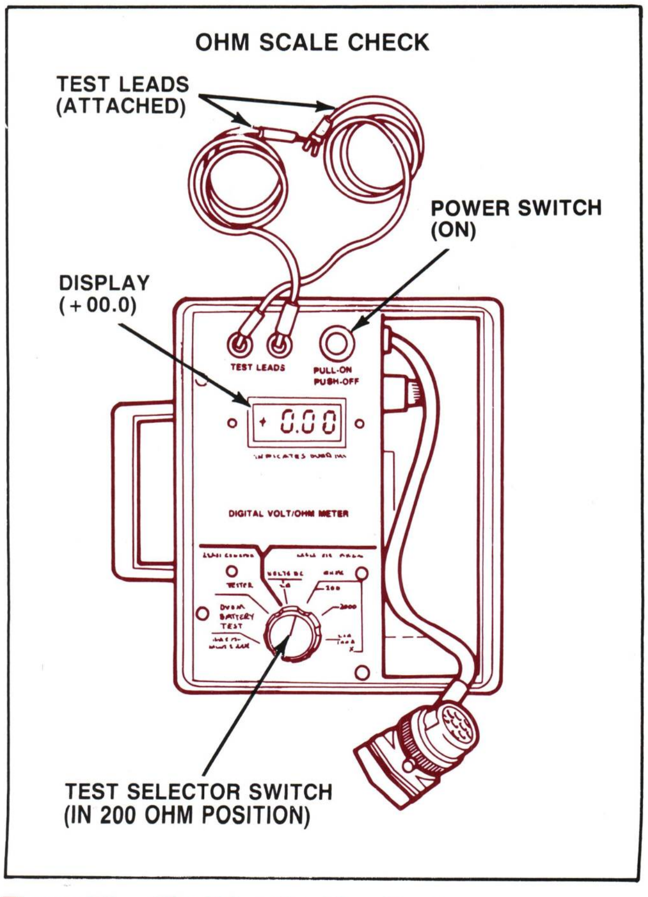


Figure 62 — Checking the Ohm Scale

Measuring Resistance (Typical)

To check resistance with a DVOM, perform the following procedure (Fig. 63):

1. Insert the test leads into the DVOM. **Remember: red to red and black to black.**
2. Pull the ON/OFF switch to the ON position.
3. Turn the test selector switch to the DVOM BATTERY TEST position and verify that the battery is in satisfactory condition.
4. Turn the test selector switch to the 200 ohm scale, and touch the ends of the test leads together. A reading of +00.1 or +00.2 is satisfactory.
5. Touch the ends of the test leads to each end of the circuit being checked. **A reading of 65.0 is obtained. This indicates that there is a 65 ohm resistance in the circuit being checked.**
6. If the test selector switch is turned to the 2000 ohm scale, and the ends of the test leads are touched to each end of the circuit being checked, a reading of 065 is obtained. **This indicates that there is a 65 ohm resistance in the circuit.**
7. If the test selector switch is turned to the 200 x 1000 ohm scale, and the ends of the test leads are touched to each end of the circuit being checked, the DVOM will read 0.00. **This indicates that the tester cannot check for such a small resistance in its current position. Remember, if 0.00 is displayed, and you are in the highest position, take the time to turn the selector switch to the next lowest position. This will verify whether there is resistance in the circuit.**

As you can see by this example, the reading would be the same in both the 200 ohm scale and the 2000 ohm scale, but there is no reading obtained in the 200 × 1000 ohm scale.

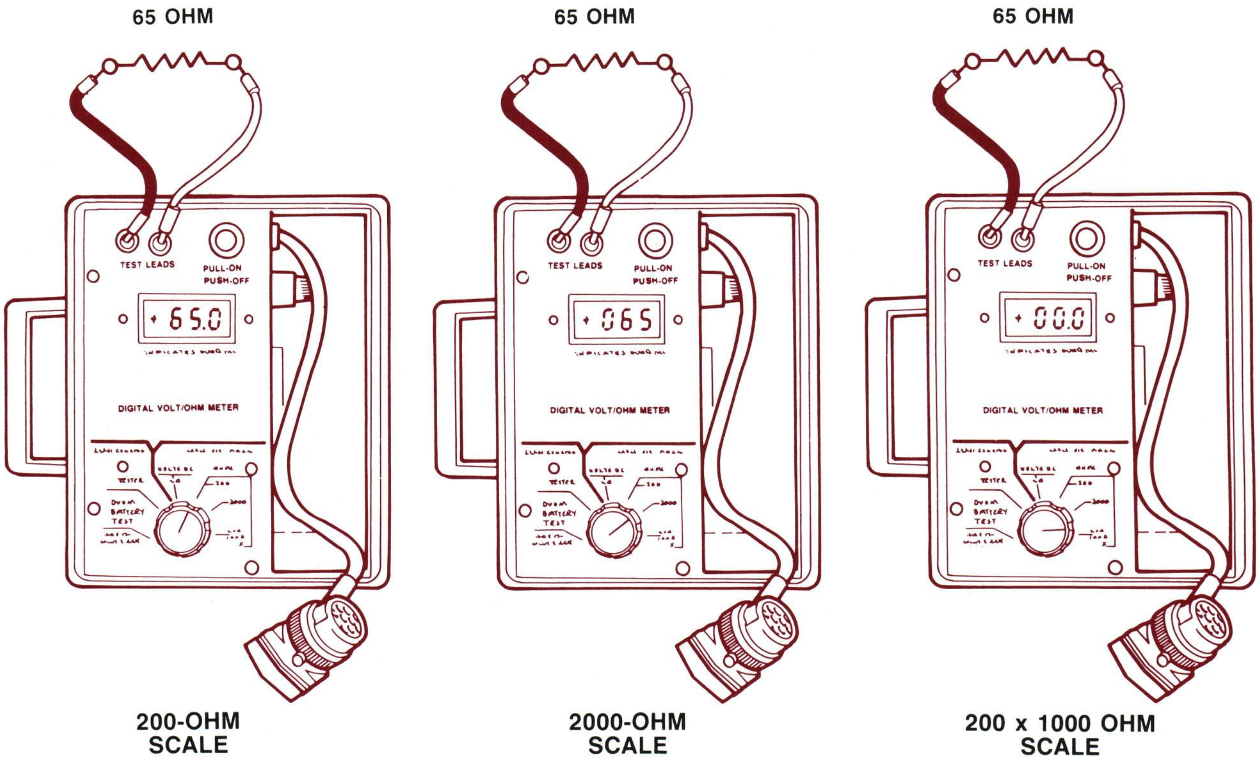


Figure 63 — Measuring a 65 Ohm Resistance with a DVOM

The following is an example of how to use the DVOM in checking for a resistance of 1250 ohms (Fig. 64).

1. Insert the test leads into the DVOM. **Remember: red to red and black to black.**
2. Place the ON/OFF switch into the ON position.
3. Turn the test selector switch to the DVOM BATTERY TEST position and verify that the battery is in satisfactory condition.
4. Turn the test selector to the 200 ohm scale, and touch the ends of the test leads together. A reading of + 00.1 or 00.2 is satisfactory.
5. Touch the ends of the test leads to each end of the circuit being checked.
6. If a reading of + 1 is obtained, turn the test selector switch to the 2000 ohm scale. The + 1 indicates that the circuit resistance exceeds the meter's ability to measure in the current range. In the 2000 ohm range, a reading of 1250 is obtained. **This indicates that there is a 1250 ohm resistance in the circuit.**
7. If the test selector switch is turned to the 200 × 1000 ohm scale, and the ends of the test leads are touched to each end of the circuit being checked, the DVOM will read 1.2. **This indicates that there is a 1200 ohm resistance in the circuit.**

As you can see by this example, a more accurate reading is obtained when the DVOM is in the 2000 ohm scale.

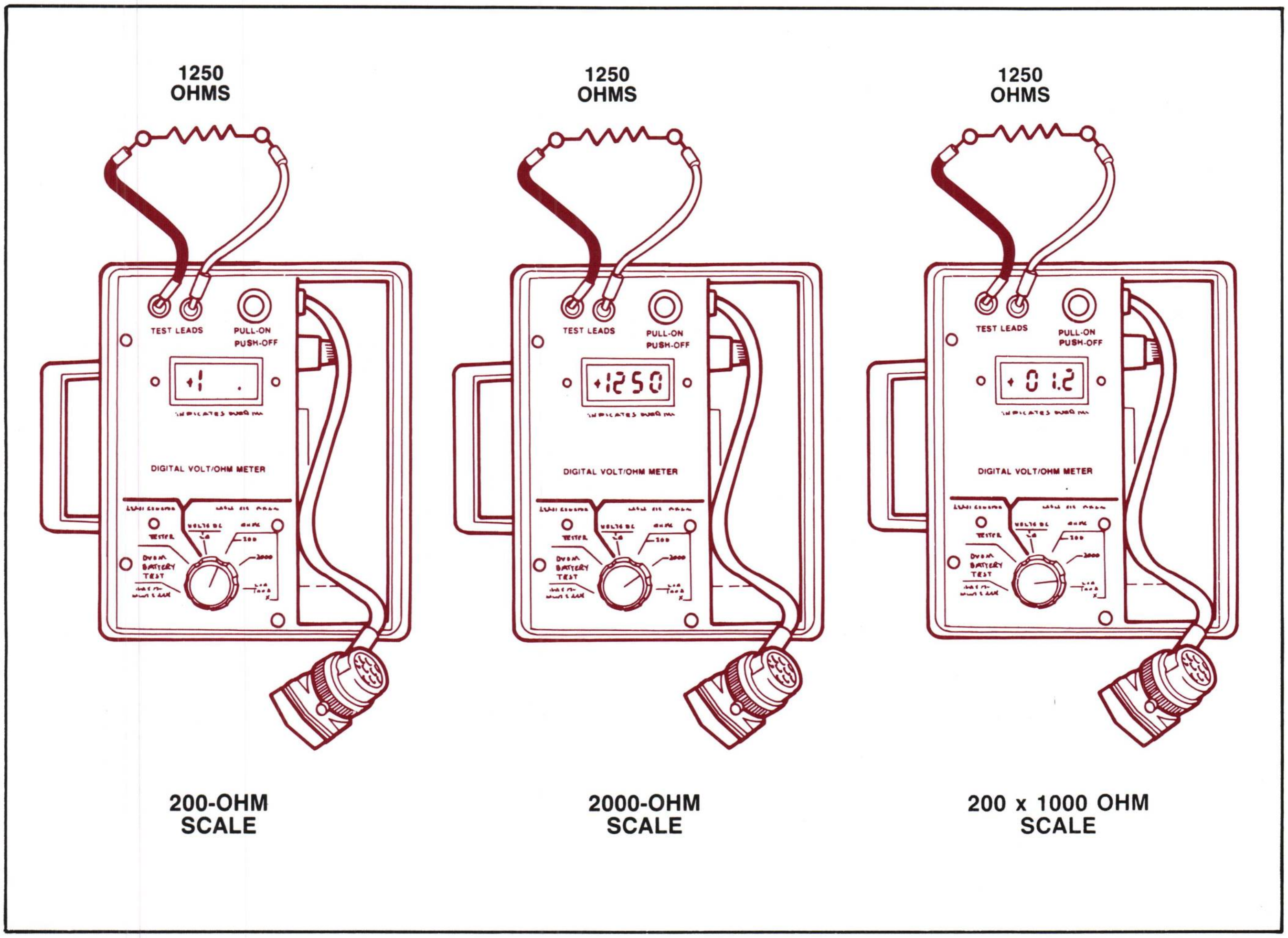


Figure 64 — Measuring a 1250 Ohm Resistance With a DVOM

TIMING LIGHT

The timing light is a specially designed strobe light. It flashes each time the ignition "fires" the spark plug to which it is connected. This timed flash is used to illuminate the engine timing mark. Because the flash only occurs when the plug fires, the engine timing mark appears to stand still when illuminated by the timing light. The engine timing mark position can then be compared to the stationary timing scale to determine how many degrees before or after Top Dead Center (TDC) the plug fires.

Most timing lights are shaped like a pistol (Fig. 65). The ON/OFF switch is located where the trigger would be on a firearm. The front of the timing light contains a bulb which is capable of flashing very rapidly (usually a xenon flash tube). Three test leads branch out from the handle (Fig. 65). The two test leads with similar clips on the ends are clipped to 12-volt power source (usually the vehicle battery). The other test lead, an inductive pickup which senses voltage inside a conductor, is clipped to the appropriate spark plug wire.

When the inductive pickup senses a voltage pulse in the plug wire, circuitry inside the timing light causes the bulb to flash. This flashing continues as long as the ON/OFF switch is depressed.

Some earlier model timing lights are equipped with a terminal which must be connected in-line between the spark plug and the plug wire. This terminal replaces the inductive pickup on the timing light test lead. Timing lights equipped with an in-line connector instead of an inductive pickup are somewhat less convenient to use; however, they are no less accurate than inductive models.

Some timing lights are available with a built-in tachometer and/or degrees advance checking feature (Fig. 65). The tachometer feature is useful when setting idle rpm and other engine speed related conditions. The advance checking feature is useful in determining mechanical advance, vacuum advance and total spark advance with the engine running.

To measure ignition advance, connect the timing light in the usual fashion. Then, start the engine and observe the timing mark with the timing light. With the timing light flashing and the timing mark visible, rotate the degrees advance dial on the timing light until you observe the engine timing mark at Top Dead Center (TDC). The degrees advance are now indicated on the timing light degrees advance dial. To determine the total advance, perform this procedure with the vacuum hose connected to the distributor vacuum unit. To determine the amount of mechanical advance, perform this procedure with the distributor vacuum hose disconnected and blocked.

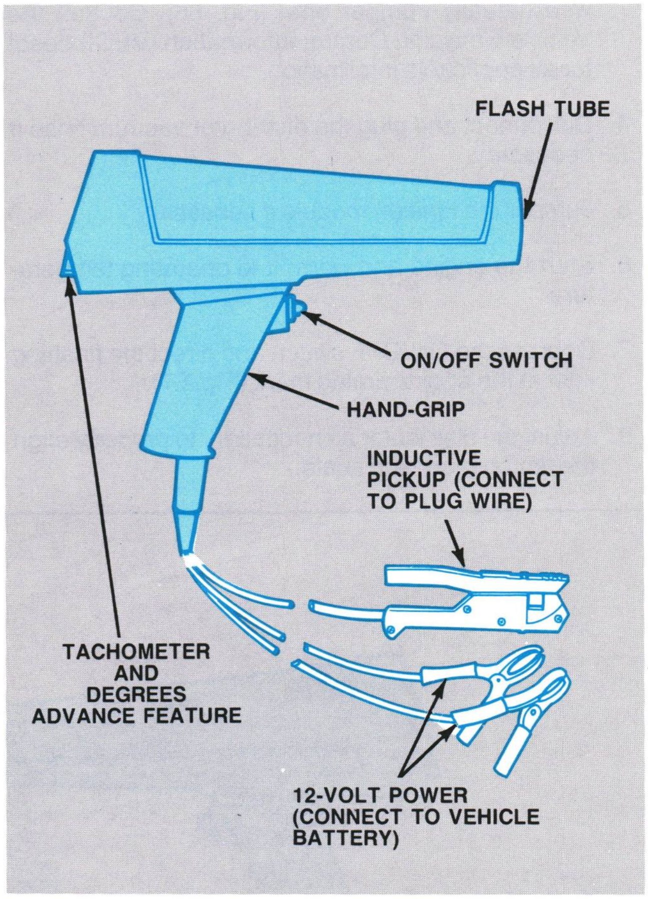

FLASH TUBE
ON/OFF SWITCH
HAND-GRIP
INDUCTIVE PICKUP (CONNECT TO PLUG WIRE)
TACHOMETER AND DEGREES ADVANCE FEATURE
12-VOLT POWER (CONNECT TO VEHICLE BATTERY)

Figure 65 — Typical Timing Light With Tachometer and Degrees Advance Feature

Checking Spark Timing (Typical)

To check spark timing using a timing light, perform the following procedure:

1. Ensure that the parking brake is engaged and the gear selector is in PARK.
2. Attach the negative and positive power leads to the vehicle battery or other convenient 12-volt power source (Fig. 66).
3. Clip the inductive lead to the appropriate spark plug wire (usually number one) (Fig. 66). Consult the Vehicle Emission Control Information (VECI) decal for all applicable information.
4. Disconnect and plug the distributor vacuum hose if necessary.
5. Jumper the ignition module if necessary.
6. Start the engine and warm it to operating temperature.
7. Depress the ON/OFF switch and direct the flashing light at the engine timing mark (Fig. 67).
8. Adjust the distributor as necessary to properly align the timing mark and scale.

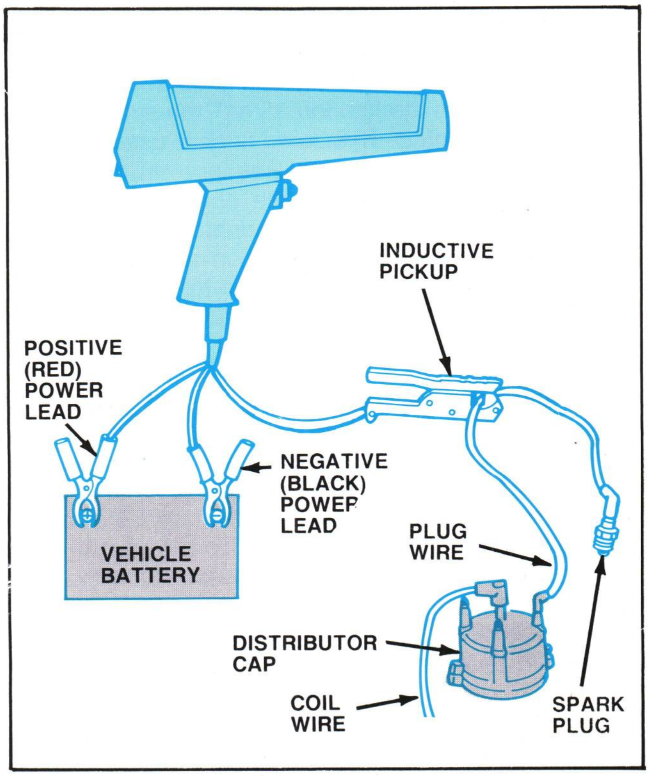


Figure 66 — Connecting the Timing Light

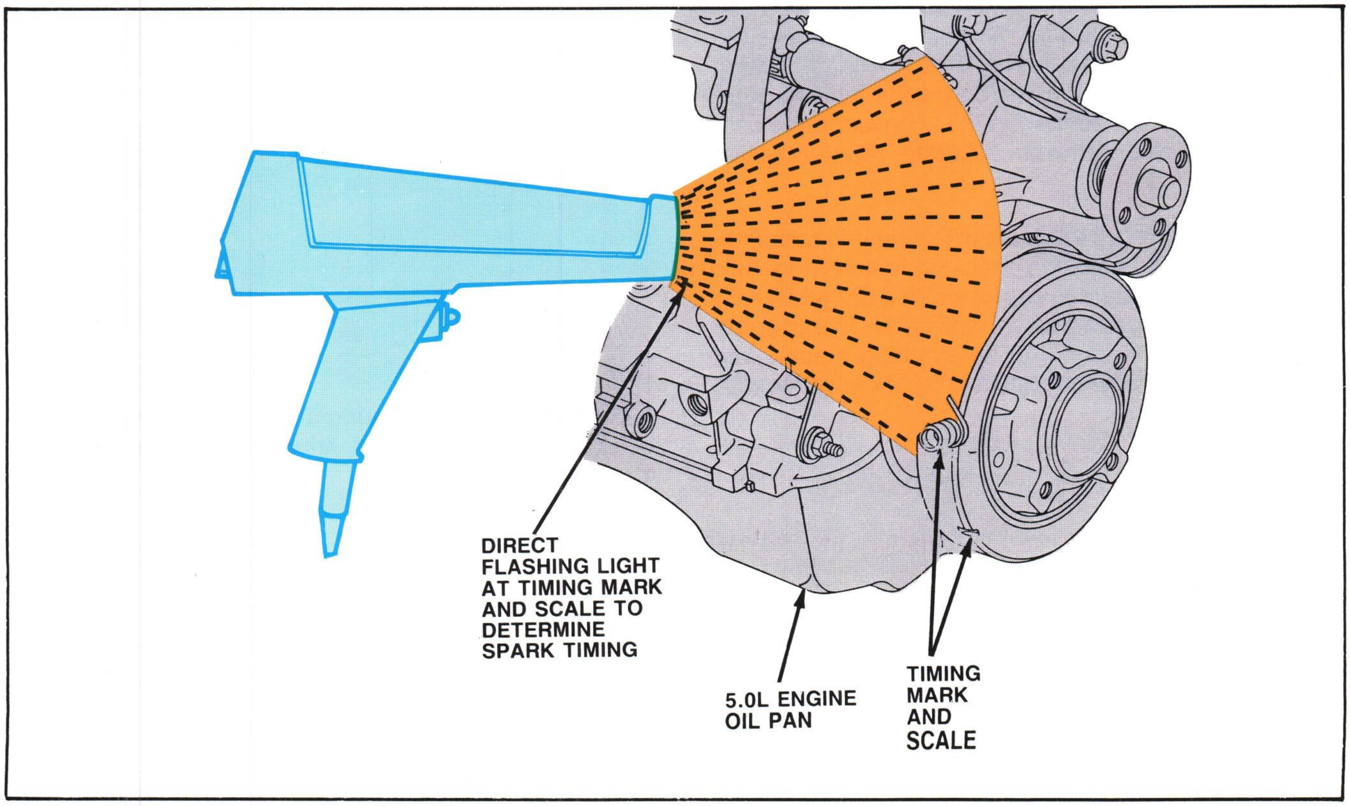

DIRECT FLASHING LIGHT AT TIMING MARK AND SCALE TO DETERMINE SPARK TIMING
5.0L ENGINE OIL PAN
TIMING MARK AND SCALE

Figure 67 — Checking Spark Timing Using the Timing Light

DIESEL DYNAMIC TIMING METER

The diesel engine, unlike the gasoline engine, has no electric ignition system signals which may be detected and used for the purpose of timing adjustment. To dynamically (engine running) time a diesel engine, the fuel line pulse, crankshaft position and combustion time must be referenced at the same time. The fuel line pulse is often monitored with a pressure transducer. Crankshaft position is monitored with a magnetic probe. Combustion is monitored by inserting a luminosity probe into one of the glow plug bores. The luminosity probe is then attached to a photocell which detects combustion.

Most diesel engines are timed statically (engine not running) by inserting locking pins into specific guides and bores. Static timing procedures require that the engine be manually rotated to precisely the right position, and locked into place with the pins. The dynamic timing procedure is usually used as a quick check of static timing. Many diesel engine manufacturers specifically prohibit timing adjustment based only on the dynamic timing procedure. The manufacturer's specifications should always be checked before performing any adjustment of diesel engine timing.

The diesel dynamic timing meter (Fig. 68) consists of a dual LCD display meter which monitors engine speed and degrees of timing, and all of the various probes and adapters necessary to connect it to many diesel engines.

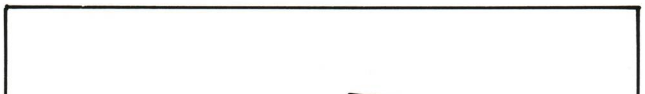


Figure 68 — Typical Diesel Dynamic Timing Meter

Fuel quality is an important factor affecting diesel engine timing. If the quality of the diesel fuel is poor, it does not ignite as readily as it should. This slow ignition of the fuel results in an indicated timing figure which is significantly different from the actual figure.

Diesel fuel quality is referred to as its cetane rating. This is checked with a cetane tester. The cetane tester measures the specific gravity of the fuel, and indicates the fuel quality on a calibrated scale. The cetane tester is discussed in detail later in this document.

Diesel Dynamic Timing Procedure (Typical)

Engine timing is verified by using the timing bracket located beside the crankshaft damper as a reference point. The timing bracket contains holes for checking dynamic timing and static timing (Fig. 69). Positioning of the bracket is critical. If it is loosened or moved, the timing will not be correct. The bracket is accurately positioned and chisel marked to the front cover during engine production. These chisel marks must always be aligned. Never loosen or remove the timing bracket.

Dynamic timing is used as a quick check for proper timing. Do not, under any circumstances, change or set engine timing based only on dynamic timing readings. Diesel engine timing is to be set only with special timing lock pins, using the static timing method.

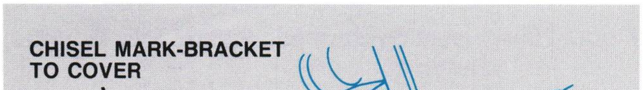


Figure 69 — Timing Pin and Probe Bracket

1. With the engine stopped, install a dynamic timing meter. Place the magnetic pickup into the timing bracket pointer hole (Fig. 70). Attach the connector from the pickup to the meter lead.

NOTE: To prevent incorrect readings, make sure that the vibration damper grooves are clean and free of debris and rust. The pickup groove in the damper must not be plugged, or readings will be inaccurate.

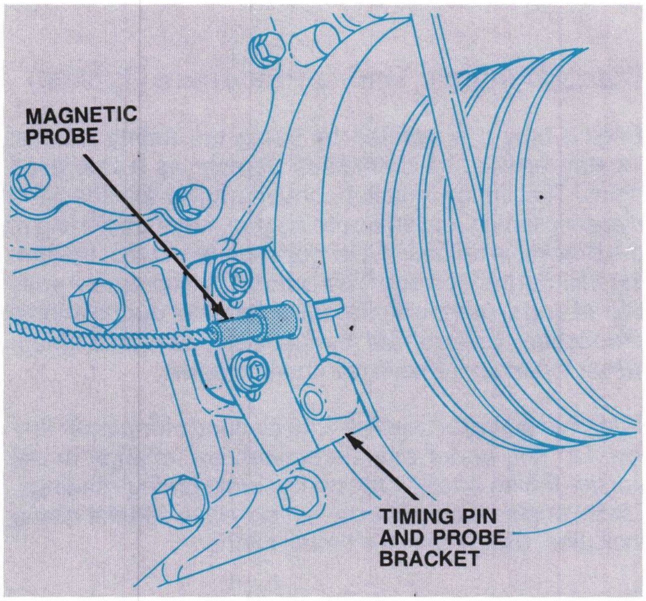


Figure 70 — Inserting Magnetic Pickup Into Timing Bracket

2. Attach the pressure transducer to the No. 1 injector line at the injector (Fig. 71). Be sure that the injector line is clean and free of paint at the transducer attachment point. Tighten the thumbscrew on the transducer finger-tight when attaching it to the injector line.

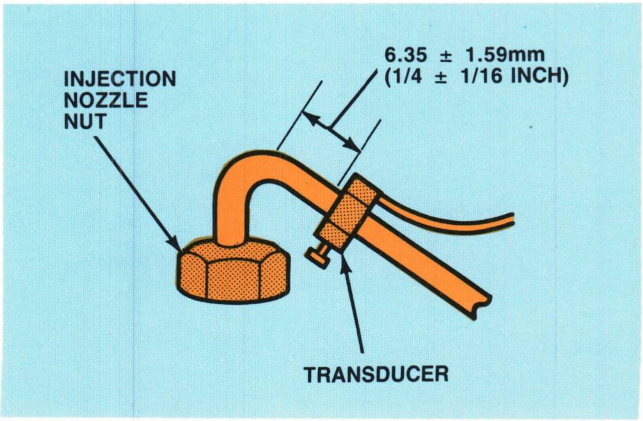


Figure 71 — Pressure Transducer Attachment

NOTE: Cracks or other damage to the pressure transducer can cause incorrect timing readings. Follow these procedures carefully when working with pressure transducers:

- Do not over-tighten the transducer; a snug fit is all that is needed. Do not use hand tools to tighten the thumb screw.
- Attach the transducer at the same location along the high-pressure line each time a check is made. The timing reading will change if the transducer is placed at a different location along the injector line.
- The transducer should be dry; wet conditions will give erratic readings. If erratic readings are observed, remove transducer, wipe line and transducer with a clean, dry cloth. Spray the transducer and line with a water-displacing material, and clamp it onto the injector line.

3. Connect the timing meter power leads to the vehicle battery and adjust the offset angle on the meter to zero degrees.

CAUTION: Be sure that all wire leads are located away from the front accessory drive belts and cooling fan. If necessary, place an "S"-hook into a convenient position, and hang the wire leads from it.

4. With the transmission in NEUTRAL or PARK and the parking brake set, start the engine. Set the engine speed at 1000 rpm with no load, and observe the timing meter reading.
5. Check the Engine Performance Specifications for the correct timing specification for the engine being serviced. Compare it the observed reading to specifications.
6. Turn the engine off. Remove the dynamic timing meter components.
7. If timing is off more than two degrees and there are indications of incorrect timing, (such as poor performance or smoke), check the static timing using the lock pins. If the engine is performing normally and there is no evidence of excessive smoke or poor performance, check all meter connections and, if necessary, have the meter calibration verified.

BATTERY/STARTER TESTER

The purpose of battery testing is to determine the state of charge and the condition of the battery. Proper testing, of course, requires that you know the battery's service specifications.

Because a hydrometer cannot be used on maintenance-free batteries, a chart has been developed showing the relationship between Open Circuit Voltage (OCV) and specific gravity. The state of charge can be determined by OCV. OCV is important when determining the correct charging time. This method for determining battery charge state is used in the following Battery Capacity Test. It is applicable to both maintenance-free and conventional batteries.

Battery/starter testers (Fig. 72) typically include an ammeter, voltmeter and a carbon pile to simulate load conditions. A load control knob permits the simulated load to be increased or decreased. The voltmeter and ammeter sometimes have separate test leads.

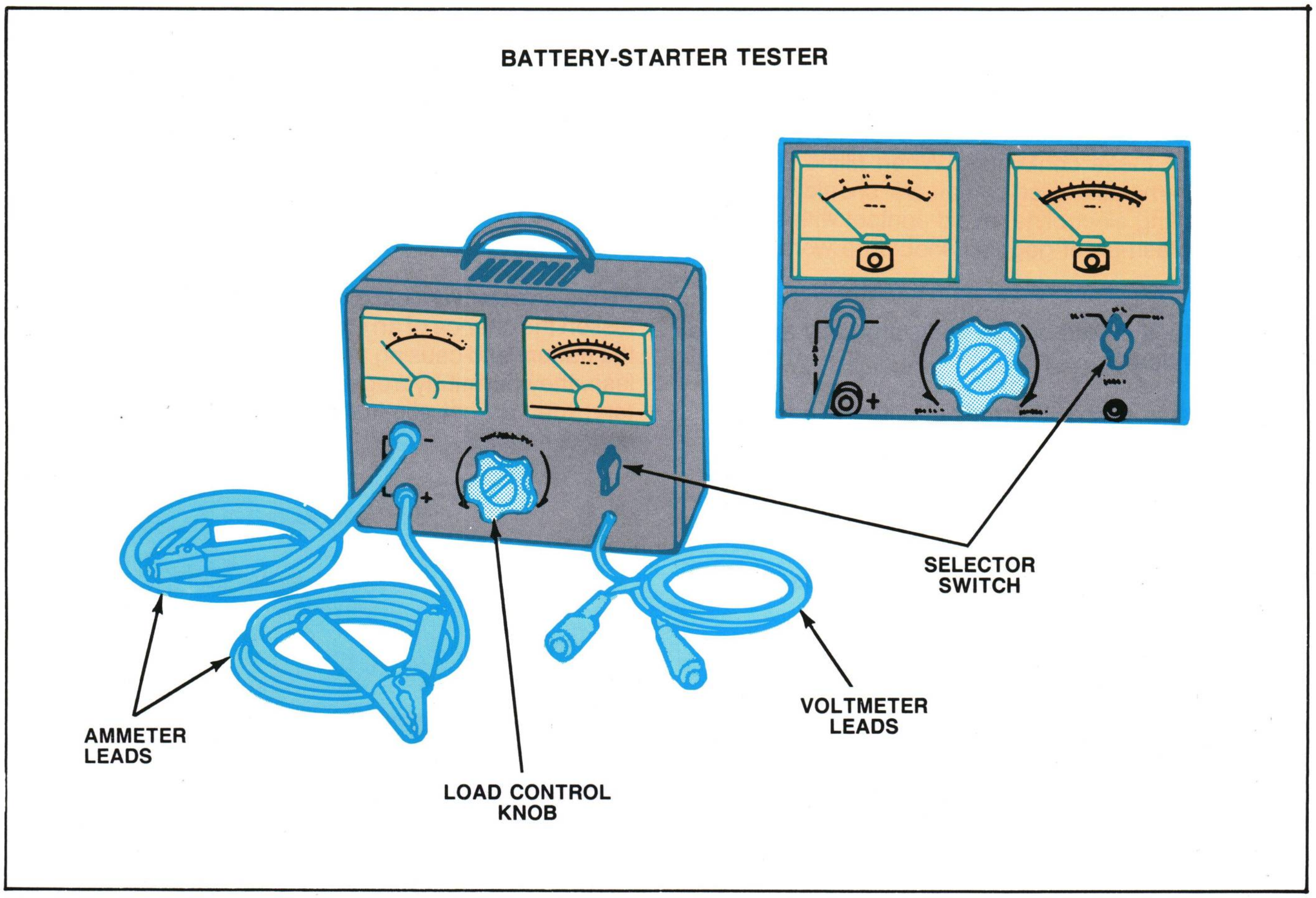


Figure 72 — Typical Battery/Starter Tester

BATTERY SAFETY

NOTE: Always refer to the shop manual before testing a battery. Follow all safety precautions in the shop manual. Also refer to the battery warning label (Fig. 73).

The following precautions should be followed when testing a battery.

Battery handling and service procedures involve two hazardous substances: sulfuric acid and hydrogen gas.

Sulfuric acid is the active ingredient in electrolyte ("battery acid"). It is a powerful acid. It will corrode all common metals, destroy paint finishes and clothing, and inflict serious burns to skin and eyes. Electrolyte is shipped in containers designed to handle acid. It should be stored in these containers. When filling batteries, special non-metallic filler containers should be used. When handling electrolyte, avoid contact with skin and clothing; splash-proof goggles should be worn for eye protection.

If electrolyte is spilled on the body, promptly apply the following antidotes:

- External — flush with large quantities of water.
- Internal — drink large quantities of water or milk, followed with milk of magnesia, beaten egg, or vegetable oil.
- Eyes — flush with water for 15 minutes and get prompt medical attention.
- Call a physician immediately.

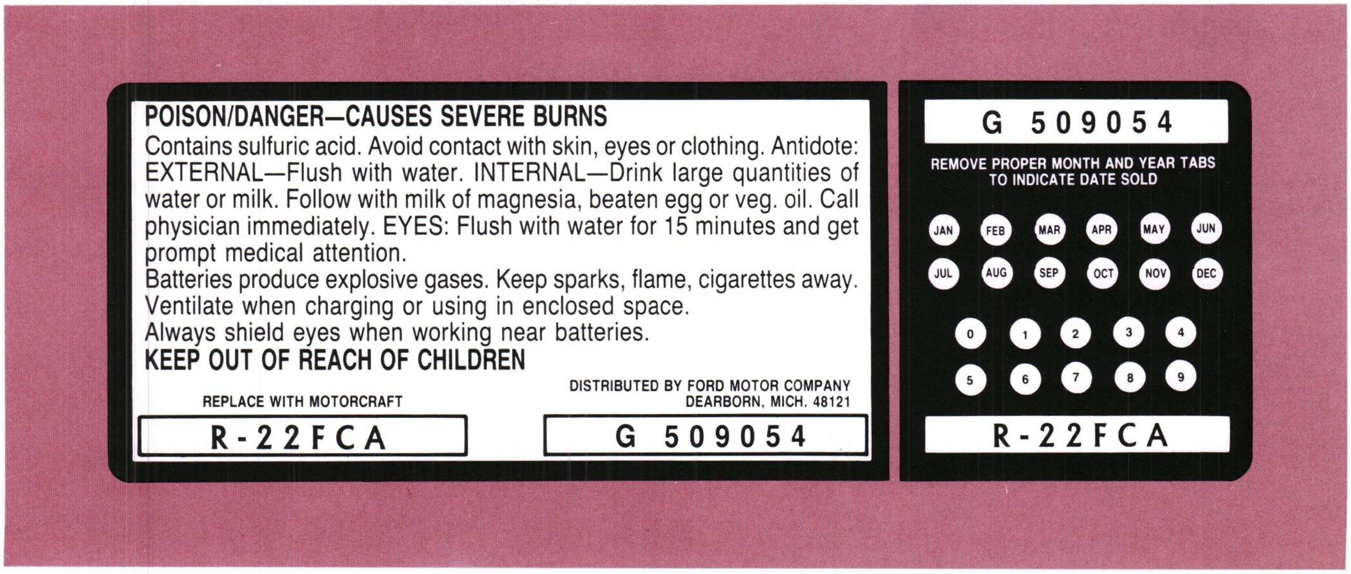
Hydrogen gas is given off during battery charging. The gas is highly explosive. Extreme caution should be taken to avoid sparks or flames anywhere near a battery which is being charged. Use extreme caution when jump-starting another vehicle.

When charging batteries, the following precautions should be taken:

- Protect eyes at all times.
- Keep the area well ventilated.
- Keep sparks, flame, and lighted cigarettes away.
- Do not remove vent caps while charging.
- Turn off charging equipment before connecting or disconnecting cable clamps.

Batteries should be kept out of reach of children at all times.

Flame arrester vent caps or gang vents are designed to lessen the chance of an external spark or flame entering the battery and causing an internal explosion. Nevertheless, they permit hydrogen gas to escape from the battery; they do not eliminate the need to guard against sparks or flame.



POISON/DANGER—CAUSES SEVERE BURNS

Contains sulfuric acid. Avoid contact with skin, eyes or clothing. Antidote: EXTERNAL—Flush with water. INTERNAL—Drink large quantities of water or milk. Follow with milk of magnesia, beaten egg or veg. oil. Call physician immediately. EYES: Flush with water for 15 minutes and get prompt medical attention.

Batteries produce explosive gases. Keep sparks, flame, cigarettes away.

Ventilate when charging or using in enclosed space.

Always shield eyes when working near batteries.

KEEP OUT OF REACH OF CHILDREN

REPLACE WITH MOTORCRAFT

DISTRIBUTED BY FORD MOTOR COMPANY
DEARBORN, MICH. 48121

R-22FCA

G 509054

G 509054

REMOVE PROPER MONTH AND YEAR TABS TO INDICATE DATE SOLD

JAN FEB MAR APR MAY JUN
JUL AUG SEP OCT NOV DEC
0 1 2 3 4
5 6 7 8 9

R-22FCA

Figure 73 — Typical Battery Warning Label

Variable Load Testing

The purpose of a variable load test is to determine whether or not a battery is capable of meeting the demands of the starting motor. The demand conditions are duplicated with the test instrument. The variable load test is also referred to as a "capacity test" or a "high rate discharge test."

These safety precautions must be observed when using a variable load tester:

1. The load control knob should always be off before connecting cables.
2. The load limit should not be maintained for more than 15 seconds.
3. The battery should not be load tested if the electrolyte temperature is below 60°F (16°C).

Test Procedure (Typical)

1. Check to make sure that the load control knob is turned to OFF (full counterclockwise).
2. Turn the voltage selector switch to the 0-20 volt scale.
3. Connect the ammeter leads (large leads) to the battery terminal; the red lead to the positive terminal and the black lead to the negative terminal (Fig. 74).
4. Connect the voltmeter leads to the battery terminals; red to positive, and black to negative. Some testers do not use separate test leads for the ammeter and voltmeter. Refer to the tool manufacturer's instructions for specific information.

NOTE: The voltmeter leads must be connected directly to the battery terminals...not to the ammeter lead clips. This must be done correctly to ensure an accurate battery terminal voltage reading.

5. Turn the load control clockwise to apply the specified load to the battery. Refer to the specific recommendations of the tester manufacturer.

NOTE: Since the part number, and not the cold cranking rating is printed on the battery, typical charts have been included to properly load the battery.

6. Maintain test load on the battery for 15 seconds.

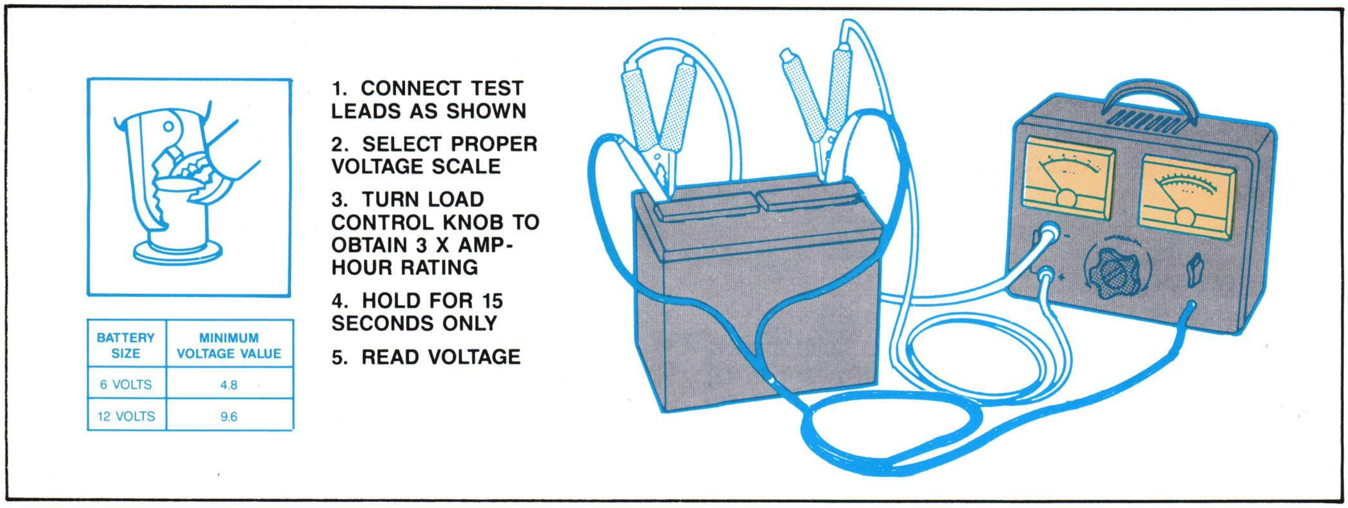
   Avoid leaving the high discharge load on the battery for more than 15 seconds.

7. At the end of 15 seconds, quickly observe the voltmeter reading and turn the load control knob to OFF.
8. If the voltmeter reading is 9.6 volts or more with the load applied after the 15-second discharge test, the battery has a good output capacity and will readily accept a charge.

   If the voltage reading obtained during the capacity test is **below** 9.6 volts, check the open circuit voltage approximately two minutes after conducting the capacity test.

   - If reading is more than 12.40 volts, replace the battery.
   - If reading is less than 12.40 volts, charge the battery at 35 amps for 20 minutes and retest.

CAUTION: Never connect or disconnect the test ammeter leads with the load control knob turned to an ON position. An arc could occur, resulting in the ignition of hydrogen gas generated by the battery.



1. CONNECT TEST LEADS AS SHOWN
2. SELECT PROPER VOLTAGE SCALE
3. TURN LOAD CONTROL KNOB TO OBTAIN 3 X AMP-HOUR RATING
4. HOLD FOR 15 SECONDS ONLY
5. READ VOLTAGE

BATTERY SIZE	MINIMUM VOLTAGE VALUE
6 VOLTS	4.8
12 VOLTS	9.6

Figure 74 — Typical Variable Load Test Connections

PNEUMATIC MEASURING DEVICES

Pneumatic measuring devices are used to check the pressure of gasses under various conditions. Some examples of conditions requiring pneumatic measuring devices are: manifold vacuum (vacuum gauge), cylinder pressure (compression gauge), refrigerant system leaks (flame or electronic leak detector), and A/C system diagnosis/charging (A/C manifold gauge set).

Pneumatic measuring devices are calibrated in several different measurement systems. These measurement systems include psi (pounds per square inch), kPa (kilopascals), inches H_2O (inches of water), and inches Hg (inches of mercury).

To explain how these systems relate to each other, convert a known pressure into its equivalent in each measuring system. For example, if we start with 32 psi (a common tire pressure), it converts into the other measurement systems as follows:

- 32 psi = 220.64 kPa (32 × 6.895 conversion factor equals 220.64). In other words, one psi equals about seven kPa.
- 32 psi = 885.64 inches H_2O (220.64 kPa × 4.014 conversion factor equals 885.64). In other words, one psi equals about 28 inches of water.
- 32 psi = 65.1 inches Hg (220.64 kPa × 0.2953 conversion factor equals about 65.1 inches of mercury). In other words, one psi equals about two inches of mercury.

NOTE: Always refer to the appropriate shop manual before performing refrigerant system diagnosis or service. Always follow the safety precautions listed in the shop manual.

NOTE: When your measuring operations involve high-pressure gas, fluid or vapor, be extremely careful that they do not exhaust directly onto your skin. Skin penetration and/or freezing can cause serious personal injury. Always wear safety goggles when measuring high-pressure gases, fluids and vapors.

NOTE: When servicing the refrigerant system, always provide adequate ventilation to prevent suffocation. Always discharge refrigerant into the garage exhaust collector.

VACUUM GAUGE

The vacuum gauge consists of a gauge calibrated in inches of mercury, and a hose which allows it to be attached to various components. It is commonly used to measure manifold vacuum (Fig. 75) — an important indicator of engine condition. However, the vacuum gauge must be carefully read and properly interpreted in order to be helpful in diagnosing engine condition.

The vacuum gauge is a valuable diagnostic aid because it "feels" the engine's intake air system as the engine is running. Any interruption of the airflow through the intake manifold is directly translated into movement of the vacuum gauge needle. For example, if an engine has a burned valve, the vacuum gauge needle will drop whenever the bad valve operates.

Abnormal vacuum gauge readings are caused by any of several factors. Sometimes, the readings are caused by a combination of things. If your vacuum gauge readings indicate mechanical trouble, you should perform further diagnosis to track the problem down.

Normal manifold vacuum readings for an engine in good condition should be between 15 and 22 in-Hg at idle. The vacuum gauge needle should remain relatively steady with the engine idling. Vacuum readings will drop about one in-Hg for every 1,000 feet above sea level.

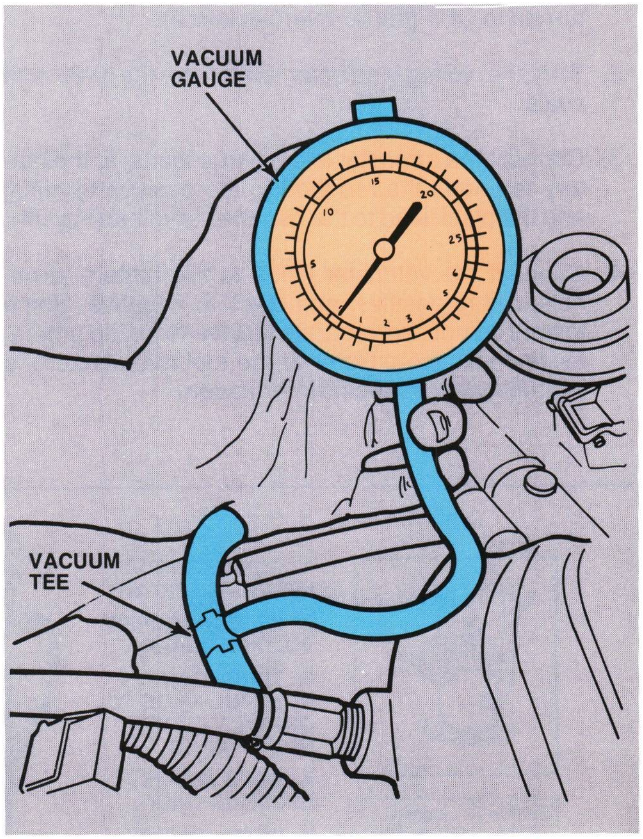


Figure 75 — Typical Vacuum Gauge Installed For Manifold Vacuum Test

Some gauges are calibrated in both vacuum and pressure (usually 0-30 in-Hg vacuum and 0-10 psi pressure Fig. 76). This gauge is a handy "all-in-one" tool which permits you to read both the vacuum and pressure ports of the fuel pump without handling two tools.

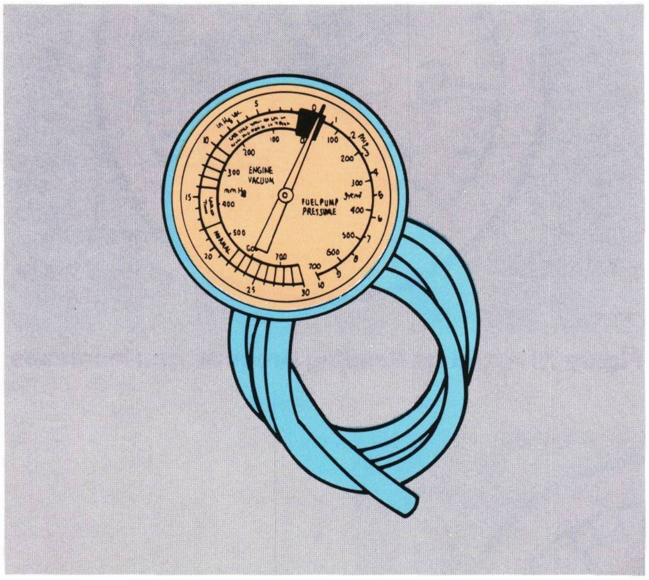


Figure 76 — Typical Vacuum Pressure Gauge

Manifold Vacuum Test (Typical)

To measure manifold vacuum using the vacuum gauge, perform the following procedure:

1. Disconnect a manifold vacuum line at the intake manifold. Install a "T" fitting into the line. Connect the vacuum gauge to the "T" fitting.
2. Place the gear selector lever in NEUTRAL.
3. Operate the engine at the specified idle rpm. If necessary, refer to the Vehicle Emission Control Information (VECI) decal in the engine compartment.
4. Check and record the reading on the vacuum gauge.
5. Compare the reading with the diagnosis chart (Fig. 77) to locate the probable engine condition. Typical vacuum gauge displays are shown in Figures 78-82.

VACUUM GAUGE READING	PROBABLE ENGINE CONDITION
15-22 IN.	NORMAL
LOW AND STEADY	LOSS OF POWER IN ALL CYLINDERS • LATE IGNITION • INCORRECT VALVE TIMING LOSS OF COMPRESSION • LEAKAGE AROUND PISTON RINGS
VERY LOW	LEAK—INTAKE MANIFOLD, CARBURETOR SPACER OR CYLINDER HEAD GASKET
NEEDLE FLUCTUATES STEADILY AS SPEED INCREASES	PARTIAL OR COMPLETE LOSS OF POWER (ONE OR MORE CYLINDERS) • LEAKING VALVE, CYL. HEAD OR INTAKE MANIFOLD GASKETS • DEFECTIVE IGNITION SYSTEM
INTERMITTENT FLUCTUATION	OCCASIONAL LOSS OF POWER • DEFECTIVE IGNITION SYSTEM • STICKING VALVE
SLOW FLUCTUATION OR DRIFTING OF THE NEEDLE	• IMPROPER IDLE MIXTURE ADJUSTMENT • LEAK AT CARBURETOR SPACER OR INTAKE MANIFOLD GASKET
STEADY BUT DROPS REGULARLY	FAULTY VALVE OPERATION • BURNT VALVE • INCORRECT VALVE CLEARANCE

Figure 77 — Manifold Vacuum Test Readings

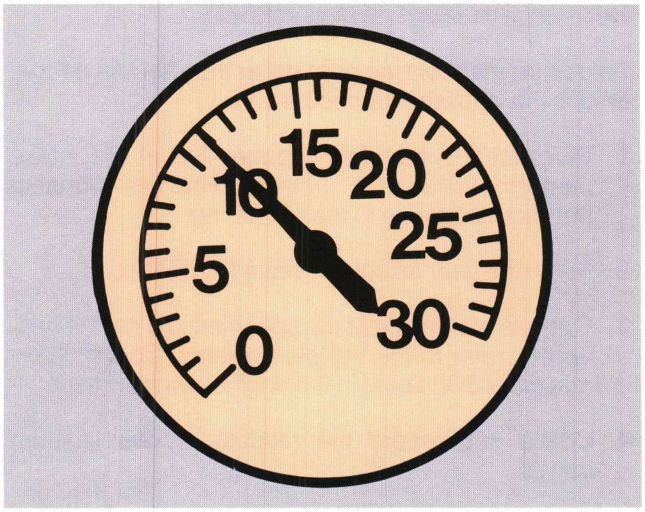


Figure 78 — Low and Steady Vacuum Gauge Reading

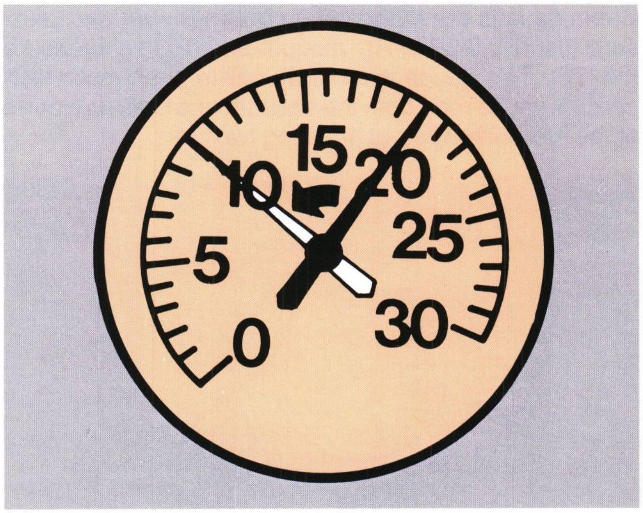


Figure 79 — Gauge Reading Drops as rpm Increases

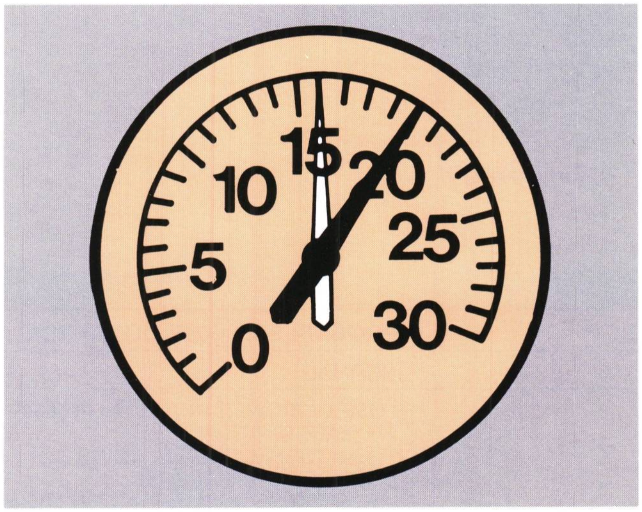


Figure 80 — Gauge Shows Intermittent Fluctuation

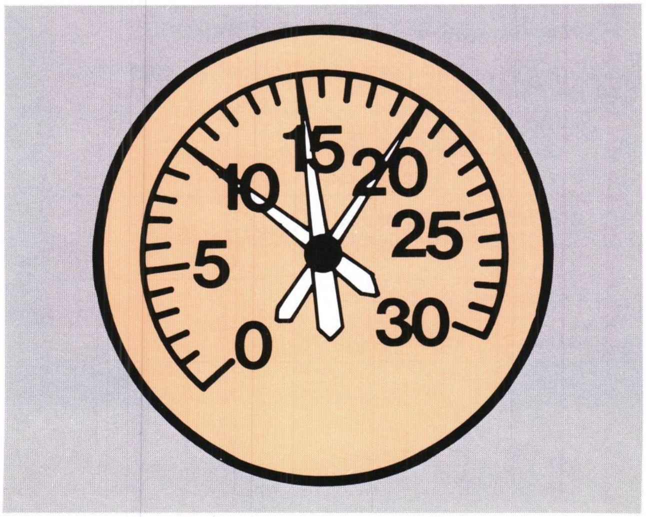


Figure 81 — Gauge Needle Drifts Slowly

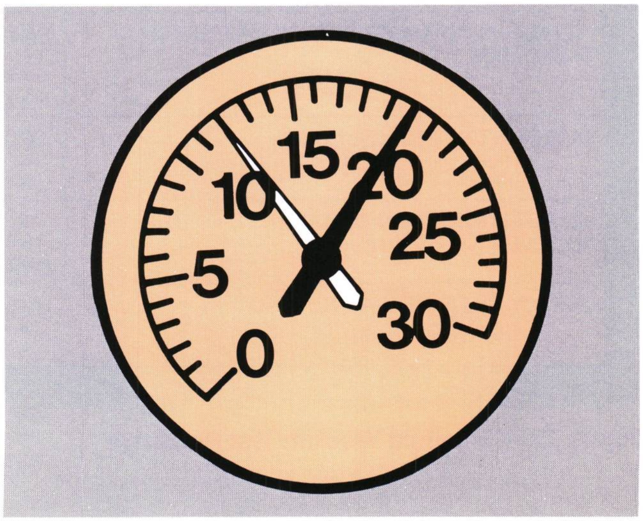


Figure 82 — Reading is Steady but Drops Regularly

COMPRESSION GAUGE (DIESEL AND GASOLINE ENGINES)

The compression gauge consists of a high pressure gauge, a hose and several fittings which permit its installation into the spark plug port of various engines. The gauge measures how much pressure is produced in the cylinder at cranking speed. By measuring cylinder pressure at cranking speed, the condition of the rings and valves in each cylinder can be determined.

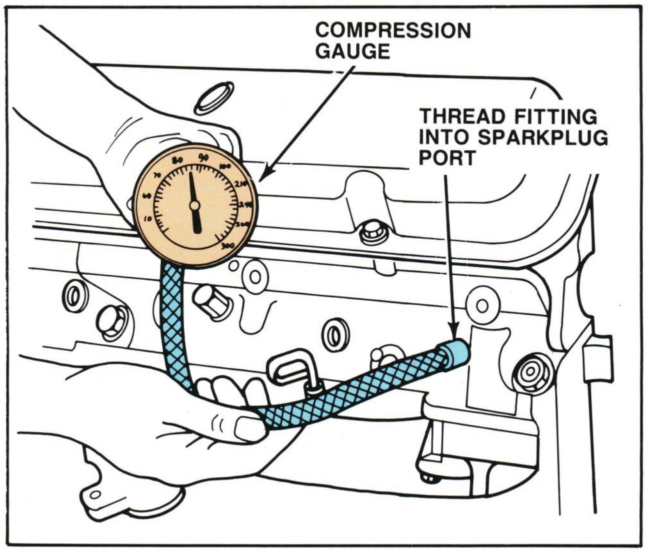


Figure 83 — Typical Gasoline Engine Compression Tester

There are two types of compression tests: "wet" and "dry." The wet compression test is performed after about a tablespoon (30cc) of oil has been squirted into the cylinder being tested. The dry compression test is performed without putting any oil into the cylinder being tested. By comparing the test results to specifications and to each other, you can determine if pressure is leaking past the piston rings or the valves.

Compression test results obtained from an engine in good condition should be as follows:

- All pressure readings should be nearly equal.
- If the lowest pressure reading is within 75 percent of the highest reading, the engine is in satisfactory condition (Example: all readings within 150 and 200 psi). Many service publications contain a chart which lists the minimum and maximum readings (high/low). These charts provide a quick reference for compression test results.

Maximum PSI	Minimum PSI	Maximum PSI	Minimum PSI	Maximum PSI	Minimum PSI	Maximum PSI	Minimum PSI
134	101	164	123	194	145	224	168
136	102	166	124	196	147	226	169
138	104	168	126	198	148	228	171
140	105	170	127	200	150	230	172
142	107	172	129	202	151	232	174
144	108	174	131	204	153	234	175
146	110	176	132	206	154	236	177
148	111	178	133	208	156	238	178
150	113	180	135	210	157	240	180
152	114	182	136	212	158	242	181
154	115	184	138	214	160	244	183
156	117	186	140	216	162	246	184
158	118	188	141	218	163	248	186
160	120	190	142	220	165	250	187
162	121	192	144	222	166		

Figure 84 — Compression Pressure Limits Chart

PNEUMATIC MEASURING DEVICES

Both gasoline and diesel engines are compression tested in the same manner. Gasoline engines are tested through the spark plug port, while diesel engines are tested through the glow plug port. The main difference between diesel and gasoline compression gauges is that diesel gauges read much higher pressures than other gauges (Fig. 85).

NOTE: Never use a gasoline engine compression gauge to test diesel engine cylinder pressure. The high pressures produced within the diesel engine can damage testers designed for use on gasoline engines.

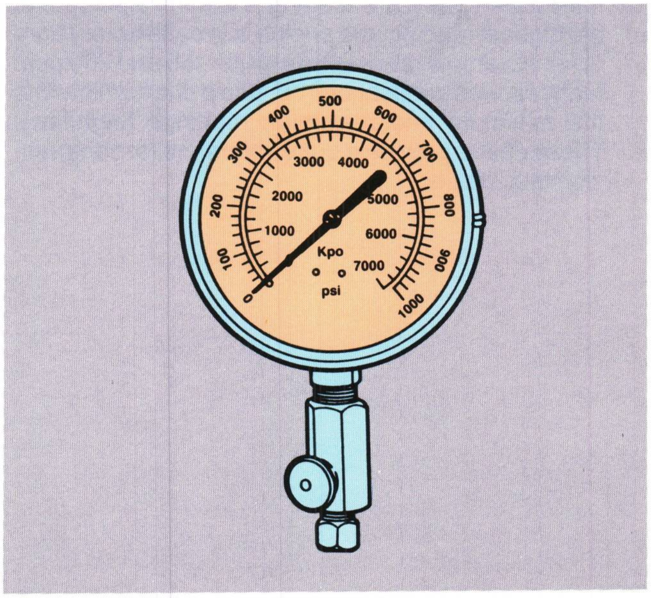


Figure 85 — Typical Diesel Compression Tester

Dry Compression Test (Typical)

1. Ensure that the crankcase oil is at the proper level. Ensure that the battery is properly charged. Run the engine until it reaches normal operating temperature. Turn off the ignition switch, then remove all spark plugs. If the engine is equipped with aluminum cylinder heads, use care when removing the spark plugs.
2. Set the throttle plates in the wide-open position.
3. Install a compression gauge into the No. 1 cylinder spark plug port.
4. Install an auxiliary starter switch into the starting circuit. With the ignition switch in the OFF position, crank the engine (using the auxiliary switch) at least five compression strokes. Record the highest reading.
5. Repeat the test on each cylinder as required to obtain the highest reading. The test should be performed in the same way when testing all cylinders.

Test Conclusion

The compression readings are considered to be within specification if the lowest reading cylinder is within 75 percent of the highest. Refer to the Compressor Pressure Limit Chart.

Wet Compression Test

If one or more cylinders read low, squirt approximately one tablespoon of heavy SAE 50 weight (or equivalent) engine oil on top of the pistons in the low reading cylinders. Repeat the compression pressure check on these cylinders.

1. If the compression improves considerably, the piston rings are at fault.
2. If the compression does not improve, the valves are sticking or seating poorly.
3. If two adjacent cylinders indicate low compression pressures and squirting oil on pistons does not increase compression, the cause may be head gasket leakage between cylinders. If oil and/or coolant is present in the cylinders, the above problem could be indicated.

   Use the Compression Pressure Limit chart when checking cylinder compression pressures. The chart has been calculated so that the lowest reading number is 75 percent of the highest reading.

Example

If, after checking the compression pressures in all cylinders, it is found that the highest reading obtained is 196 psi and the lowest pressure reading is 155 psi, the engine is within specification. The engine's compression is considered to be satisfactory.

CYLINDER LEAKAGE TESTER

The cylinder leakage tester consists of a pressure gauge, regulator, air line adapter, and various spark plug port adapters. By connecting the gauge assembly to a supply of shop air, the percentage of leakage from each cylinder can be measured. The air escaping from the cylinder usually causes a hissing sound from various engine parts; this sound is used to help locate the source of leakage.

The cylinder leakage gauge provides a method other than compression testing to determine cylinder leakage. The cylinder leakage test makes it possible to separate and identify leaks from the exhaust valve, intake valve, piston rings, head gaskets, cylinder block or cylinder head cracks which allow leakage into the cooling system.

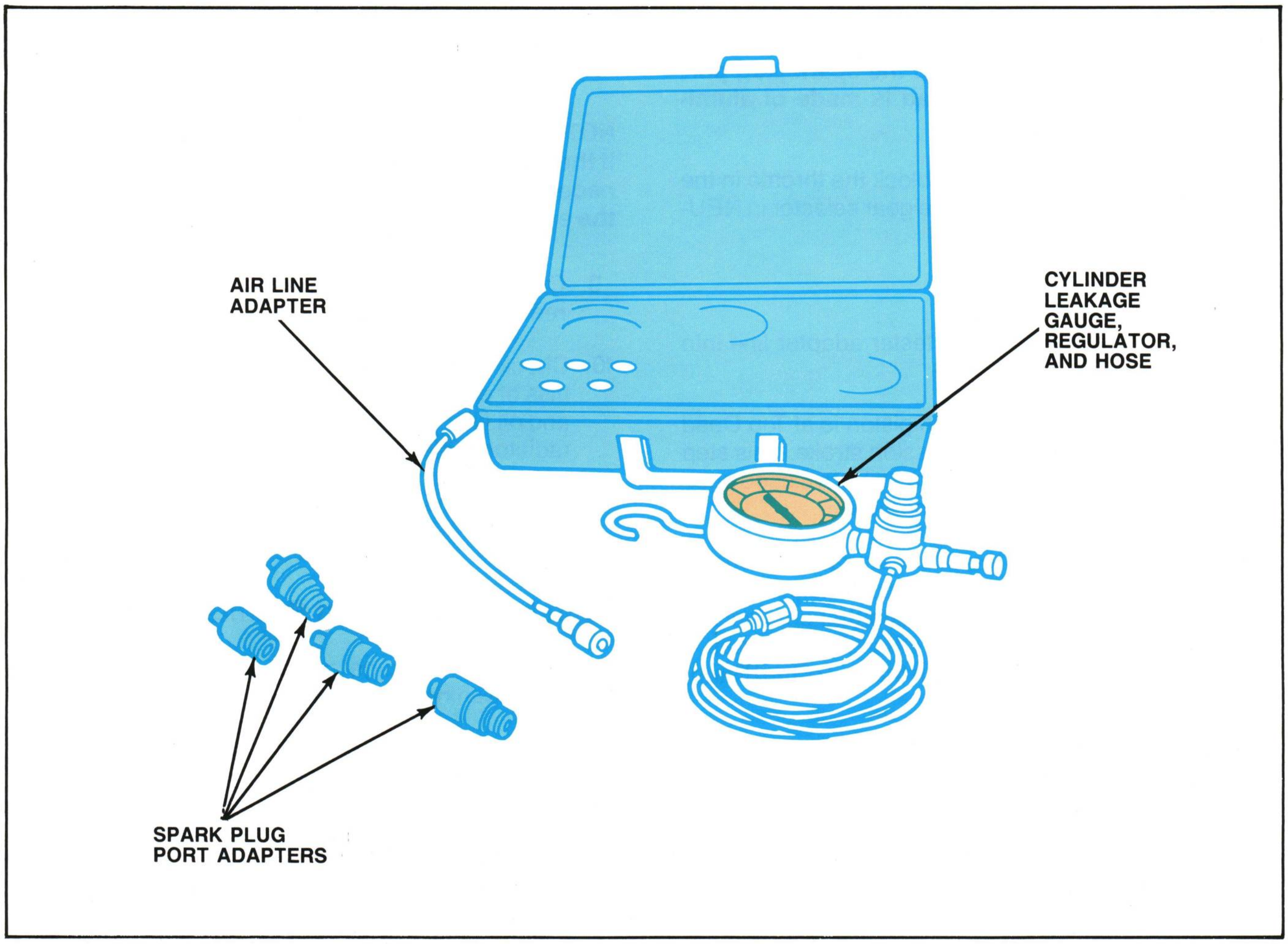

AIR LINE ADAPTER
CYLINDER LEAKAGE GAUGE, REGULATOR, AND HOSE
SPARK PLUG PORT ADAPTERS

Figure 86 — Typical Cylinder Leakage Tester

Cylinder Leakage Test (Typical)

To measure cylinder leakage, perform the following procedure:

1. Inspect the coolant level and add as required. Do not reinstall the radiator cap.
2. Run the engine until normal operating temperature is reached, then turn the engine off.
3. Remove all spark plugs.

   NOTE: Use care not to strip the spark plug port threads if the cylinder head is made of aluminum.

4. Remove the air cleaner and block the throttle in the wide-open position. Place the gear selector in NEUTRAL.
5. Remove the oil filler cap.
6. Install the cylinder leakage tester adaptor line into the spark plug port.
7. Turn the engine over until the piston is at Top Dead Center (TDC) on the compression stroke. This step is critical because the valves must be in closed position to seal the combustion chamber.

   Depending upon the tester's manufacturer, one of two methods is used to determine if the piston is at TDC. One method uses a whistle that connects to the tester adaptor line; the other method uses a TDC indicator that is placed on the end of the distributor shaft.

   If the cylinder leakage detector is equipped with a whistle:

   a. Install the whistle on the end of the adaptor line.

   b. While cranking the engine over slowly, listen for the whistle to stop sounding. When the whistle stops, stop cranking. The cylinder is now at TDC.

   If the cylinder leakage detector is equipped with a TDC indicator:

   a. Remove the distributor cap and rotor.

   b. Put the TDC indicator on the end of the distributor shaft.

   c. Position the TDC indicator with a reference point (4, 6 or 8), depending on the engine, lined up with any mark.

   d. Crank the engine over slowly until the next reference point (4, 6 or 8) lines up with the mark. The next cylinder in the firing order is now ready to test.

8. Connect the tester hose to the adaptor hose and pressurize the cylinder with compressed shop air. The air source should maintain a minimum of 70 psi (483 kPa) and a maximum of 200 psi (1380 kPa). For testing, 80 psi (552 kPa) is recommended.

NOTE: Watch the engine fan or pulleys for movement. If they move, the cylinder was not at TDC and it will be necessary to repeat Step 7. Do not attempt to crank the engine with the tester hose connected.

9. Observe and record the cylinder leakage gauge reading.
10. Check for the source of leakage by listening for the hiss of escaping air at the carburetor, exhaust pipe, and oil filler opening. Also look for air bubbles in the radiator coolant.
11. Repeat Steps 6 through 10 for remaining cylinders to be tested.

Cylinder Leakage Test Results

- All cylinder leakage gauge indications should be equal, with no more than 20 percent leakage.
- If escaping air is heard at the carburetor or throttle body, an intake valve is leaking.
- If escaping air is heard at the oil filler opening, the piston rings are worn or the cylinder wall or piston is damaged.
- If air is escaping through a blown head gasket to an adjacent cylinder, it will be heard at the spark plug port of the cylinder that the air is leaking into.
- If you see a stream of bubbles rising in the radiator, the cylinder head or block may be warped, cracked, or the head gasket may be blown.
- If you hear escaping air at the exhaust pipe, an exhaust valve is leaking.

CHEMICAL COMBUSTION LEAK DETECTOR

The chemical combustion leak detector consists of a squeeze-bulb, sight glass and special chemical test fluid (Fig. 87). This tester is used to detect combustion gasses in the coolant. If the cylinder block, head or head gasket is leaking combustion gasses into the coolant, these gasses can be detected for diagnostic purposes. The tester operates by drawing air from the cooling system through special test fluid. The color of the test fluid will change if any combustion gasses are present in the cooling system.

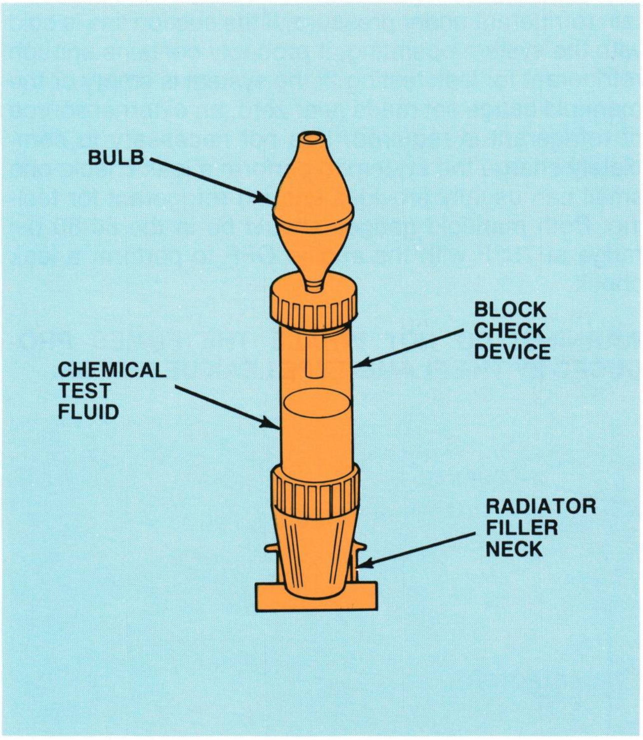


Figure 87 — Typical Chemical Combustion Leak Detector

Chemical Combustion Leak Test (Typical)

To chemically check for combustion leaks, perform the following procedure:

1. Drain coolant from the radiator until the coolant level is 2-3 inches below the neck of the radiator.
2. With the radiator cap removed, run the engine until normal operating temperature is reached.
3. Remove the bulb from the combustion leak tester and fill with test fluid to the level indicated. Reinstall the bulb on the tester.
4. With the engine running, insert the combustion leak tester firmly into the neck of the radiator.
5. Force radiator gases through the test fluid by squeezing the bulb for approximately one minute.
6. Observe the color of the test fluid.
   - If the fluid color remains blue-green, no combustion leak is present.
   - If the test fluid turns yellow, a combustion leak is present. To further isolate the location of the leak, continue with the following steps.
7. On in-line engines, remove one spark plug wire at a time, allowing the engine to idle for a few minutes to purge the cooling system of combustion gases from the previous test. Repeat Steps 3 through 6 on each cylinder until all leaks are located.
8. On V-type engines, disconnect the spark plug wires on one bank. Run the engine for approximately five minutes to purge the cooling system of combustion gases. Repeat Steps 3 through 6.
   - If the test fluid remains bluegreen, the leak is in the non-firing bank.
   - If the fluid turns yellow, the leak is in the firing bank. To further isolate the source of leakage, perform the procedures as outlined in step 7 on the bank of cylinders that indicate a leak.

FLAME-TYPE REFRIGERANT LEAK DETECTOR

The flame-type refrigerant leak detector consists of a burner, reaction plate, search hose, valve and propane cylinder (Fig. 88). With the burner lit, the flame will change color when the search hose is placed against a refrigerant leak. When used properly, the flame-type leak detector provides a simple and inexpensive method of locating refrigerant leaks.

The smaller the burner flame is, the more sensitive the detector is to refrigerant leaks. Therefore, the flame should be kept as small as possible to ensure accuracy. When properly adjusted, the flame should be barely visible (Fig. 89).

If the copper reaction plate is burned away, it should be replaced. The flame-type leak detector operates on the principle that refrigerant burned in a controlled flame over a heated copper plate produces noticeable color changes.

If the surrounding area is contaminated with refrigerant gas, the leak detector will show the presence of refrigerant all of the time. It is important that the flametype detector be used in a well-ventilated area. Use a fan even in a well ventilated area to remove small traces of refrigerant vapor.

The color to which the flame changes varies with the amount of refrigerant sensed by the detector. When the detector senses refrigerant, the flame changes to a bright blue-green color.

To perform a leak test, the refrigerant system must contain refrigerant under pressure. If the suction line is cold with the system operating, it probably contains enough refrigerant for leak testing. If the system is empty or the manifold gauge set reads near zero, an external source of refrigerant is required. It is not necessary to completely charge the system to perform a leak check; one small can usually provides enough refrigerant for testing. Both manifold gauges should be in the 60-80 psi range at 75°F with the engine OFF to perform a leak check.

WARNING: DO NOT INHALE THE FUMES PRODUCED BY THE FLAME-TYPE LEAK DETECTOR.

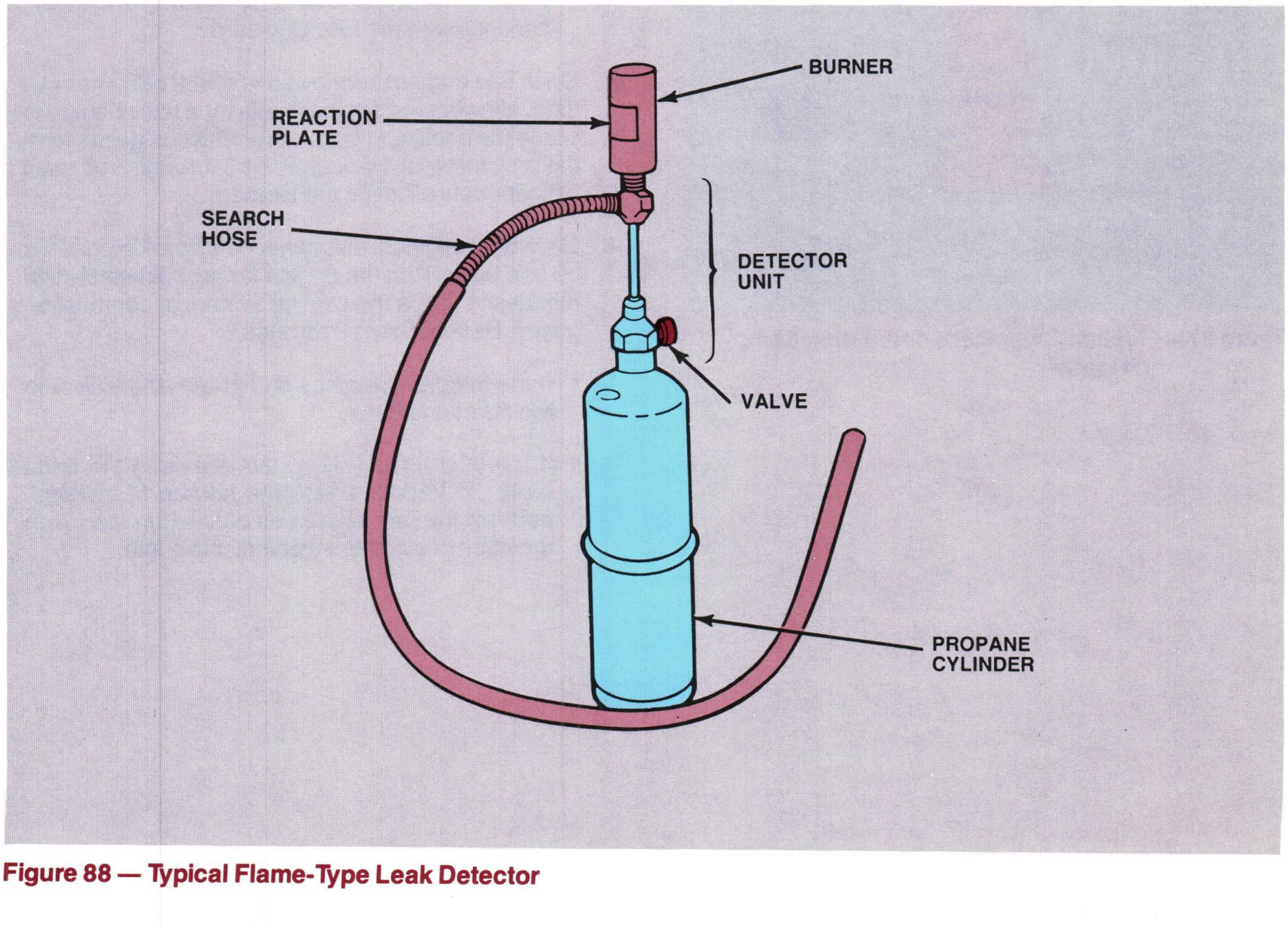


Figure 88 — Typical Flame-Type Leak Detector

SAFETY PRECAUTIONS FOR PROPANE LEAK DETECTOR USE

Care must be taken when using the flame-type detector.

- Do not inhale the fumes from the detector.
- Do not use the detector around highly explosive materials.
- Keep the stove or flame from contacting any surfaces which can be readily damaged by heat.
- Use in a well-ventilated area.

Leak Testing (Typical)

To check for refrigerant leaks using the flame-type leak detector, perform the following procedure:

Follow these steps to light the detector.

1. Open the control valve slightly.
2. Ignite the escaping gas at the stove.
3. Using the control valve, adjust the flame to approximately 3/8 inch above the reactor plate (Fig. 89).
4. Allow the reactor plate to become red hot (Fig. 89). The detector will not be effective unless the reactor plate is red hot.
5. Readjust the flame to 3/8 inch above the reactor plate.
6. The size of the flame is critical; a flame no higher than 3/8 inch above the reactor plate is desirable. A large flame will find only a large leak (Fig. 89).

When checking for leaks:

- Hold the stove in a nearly vertical position.
- The search hose should be moved along the underside of the hose, fittings, etc., since refrigerant is heavier than air and will fall. The refrigerant from a leak requires a small amount of time to travel through the search hose to the reactor plate. It is important to move the search hose SLOWLY if leak locations are to be accurately pin-pointed.

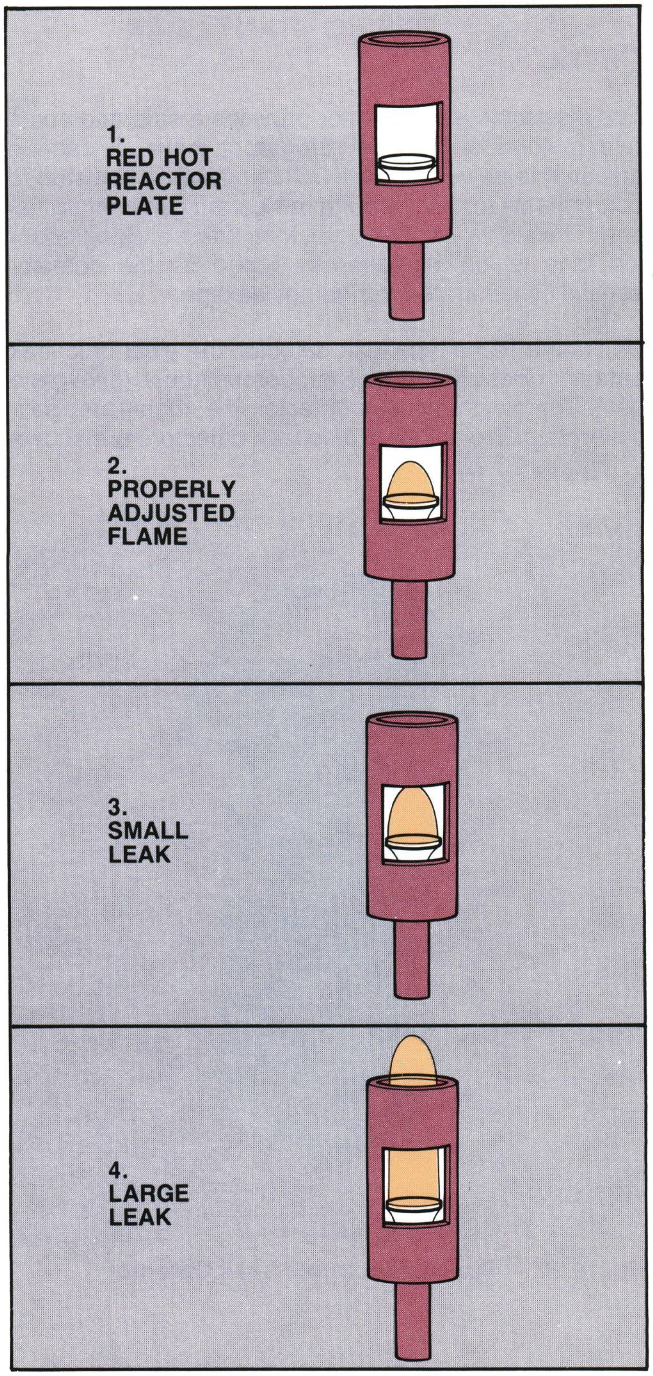


Figure 89 — Examples of Different Leak Detector Flames

ELECTRONIC REFRIGERANT LEAK DETECTOR

The electronic leak detector provides a safe and accurate method of locating refrigerant leaks. It can be adjusted to be very sensitive. It can also be adjusted to compensate for background refrigerant gas contamination. The electronic leak detector emits a clicking/beeping tone which increases in speed as the detector senses concentrated refrigerant leakage.

Unlike the flame-type leak detector, the electronic leak detector does not produce dangerous fumes (phosgene gas). The electronic leak detector is automatically self-calibrating. Typical electronic leak detectors are shown in Figures 90-92.

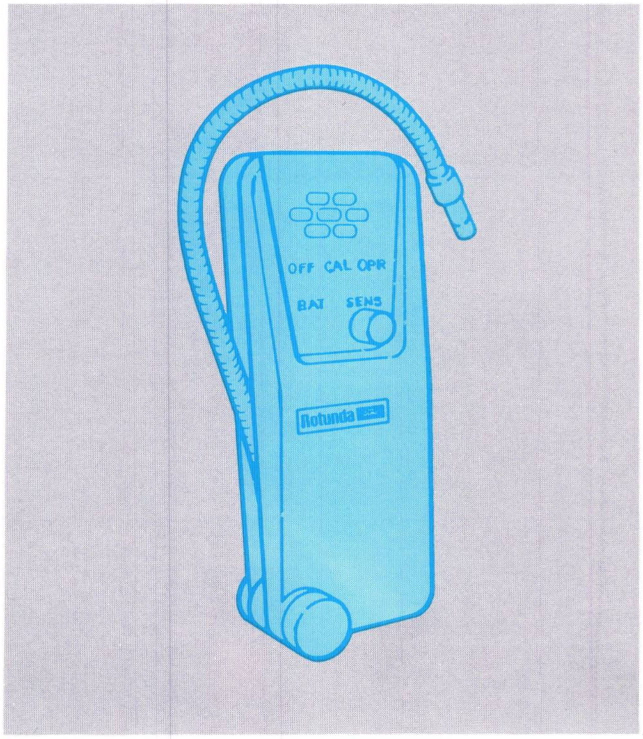


Figure 90 — Typical Electronic Leak Detector

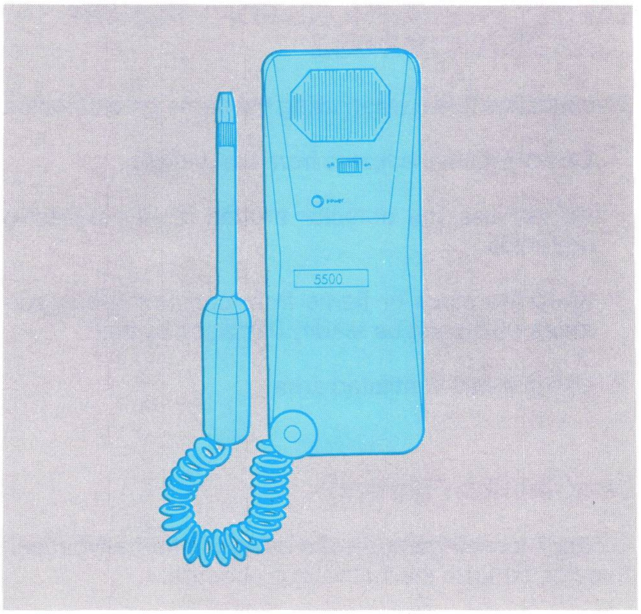


Figure 91 — Electronic Leak Detector with Battery Operated Pump

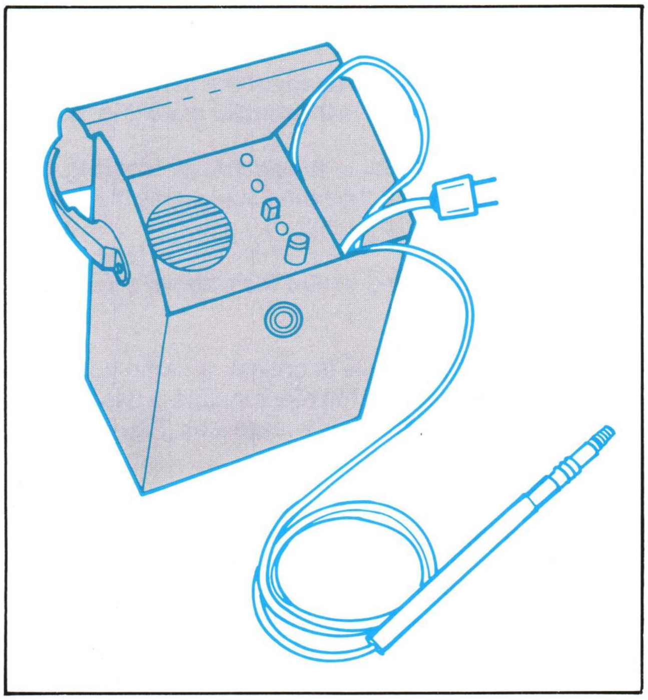
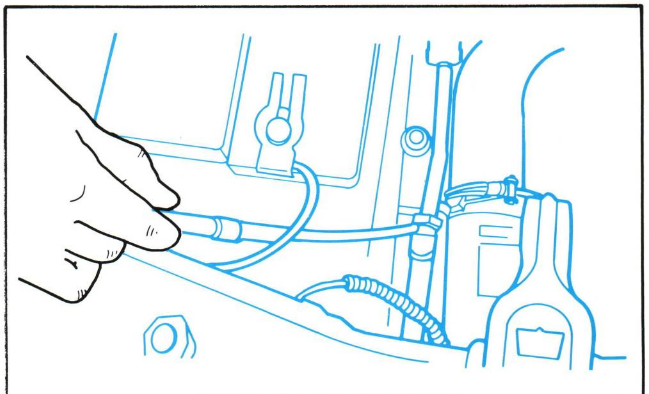
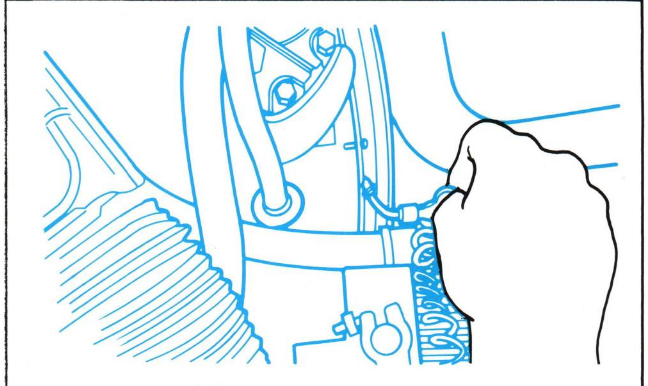


Figure 92 — Typical 110-Volt Electronic Leak Detector

Most leaks are found at fittings and connections. Since refrigerant is heavier than air and tends to fall, move the leak detector probe tip slowly along the underside of the following components: fittings, connections, refrigerant controls, compressor, condenser, accumulator, or receiver/drier (Fig. 93). If the suspected leak is not found, leak test the evaporator and the compressor shaft seal.



CONDENSER FITTINGS



COMPRESSOR CLUTCH

Figure 93 — Typical Leak Test Locations

To perform a leak test, the refrigerant system must contain refrigerant under pressure.

If the suction line is cold with the system operating, it probably contains enough refrigerant for leak testing. If the system is empty or the manifold gauge set reads near zero, an external source of refrigerant is required. It is not necessary to completely charge the system to perform a leak check; one small can usually provides enough refrigerant for testing. Both manifold gauges should be in the 60-80 psi range at 75° F with the engine off to perform a leak check.

Evaporator Leak Testing (Typical)

To leak check the evaporator, perform the following procedure:

1. Operate the climate control system in the HEAT position for a few minutes to dry the evaporator and case.
2. Disconnect the blower power lead to stop the blower and allow any leaking refrigerant to settle to the bottom of the case.
3. Place the leak detector control switch in the ON position. The detector will automatically calibrate itself when it is turned on.
4. Place the detector probe at the evaporator case water drain opening to test for the presence of refrigerant.
5. If the detector senses refrigerant, the ticking/beeping tone will increase in ticks/beeps per second.
6. To pinpoint leaks, move the detector probe at approximately one inch (25mm) per second.
7. Read and follow the instructions included with the detector for specific operating and handling techniques.

A/C MANIFOLD GAUGE SET

The manifold gauge set is the main tool used for refrigeration system testing and service. It permits refrigerant to be directed to various ports to accomplish service and testing. The manifold gauge set consists of the following: a low-pressure gauge, a high-pressure gauge, a center manifold connecting the two gauges, low- and high-pressure hand valves, and service and supply hoses (Fig. 94).

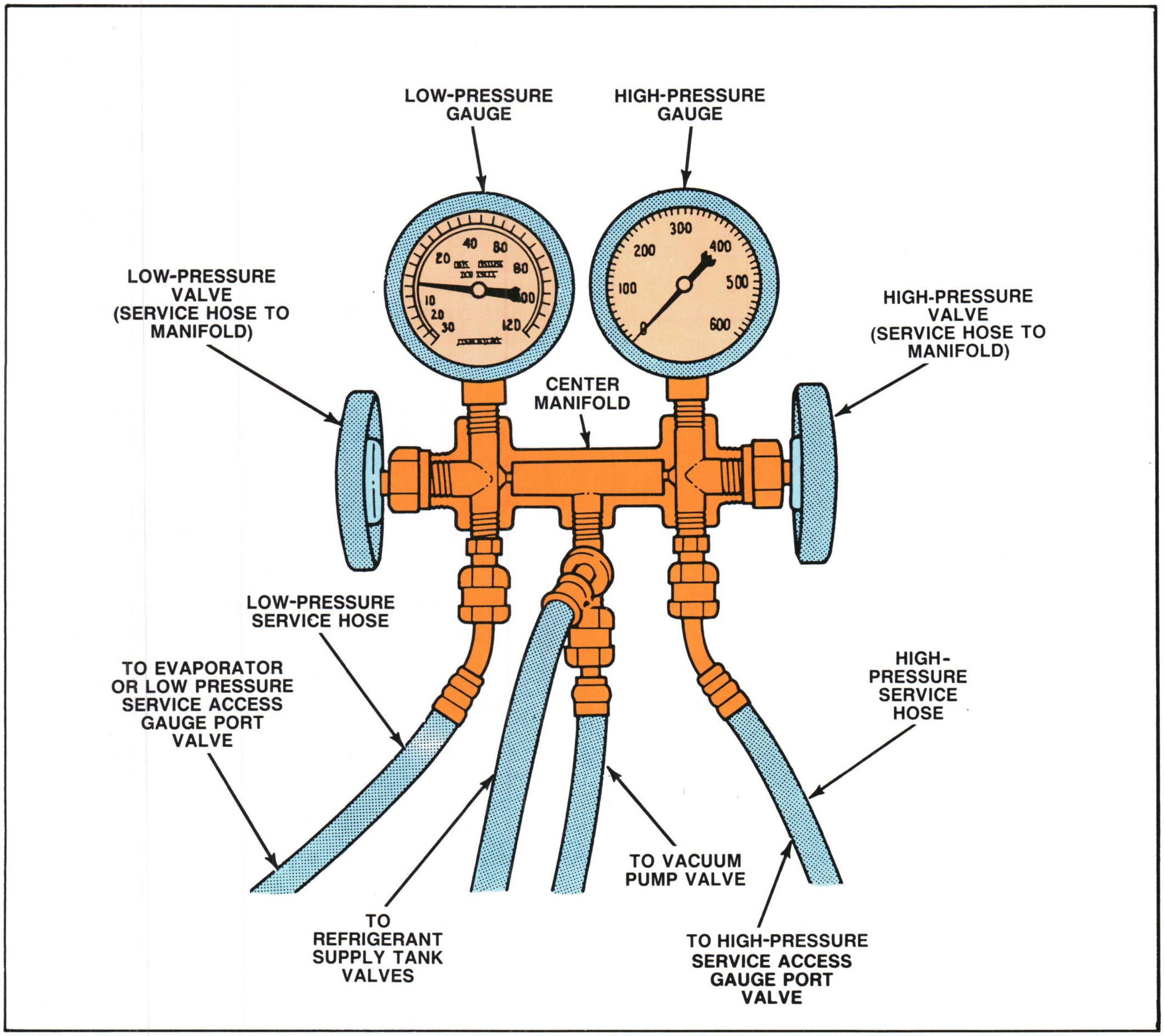

LOW-PRESSURE GAUGE
HIGH-PRESSURE GAUGE
LOW-PRESSURE VALVE (SERVICE HOSE TO MANIFOLD)
HIGH-PRESSURE VALVE (SERVICE HOSE TO MANIFOLD)
CENTER MANIFOLD
LOW-PRESSURE SERVICE HOSE
TO EVAPORATOR OR LOW PRESSURE SERVICE ACCESS GAUGE PORT VALVE
HIGH-PRESSURE SERVICE HOSE
TO VACUUM PUMP VALVE
TO REFRIGERANT SUPPLY TANK VALVES
TO HIGH-PRESSURE SERVICE ACCESS GAUGE PORT VALVE

Figure 94 — Typical Manifold Gauge Set

LOW-PRESSURE SIDE

The **low-pressure side** of the set is a compound gauge which measures either vacuum or pressure. The gauge is calibrated in inches of mercury (in-Hg), and pounds per square inch (psi), respectively. The gauge may also have scales which convert the pressure/vacuum readings to the relative evaporator temperatures for Refrigerant-12, R-22 and R-502. Low pressure is also referred to as suction pressure, since it is measured in the line to the compressor inlet.

The **control valve** for the low-pressure side is a "**hand valve.**" It is located below the compound gauge, and opens or closes the low-pressure side hose to the **service hose** for charging the system. The gauge itself is open to the low-pressure side hose at all times.

HIGH-PRESSURE SIDE

The **high-pressure** side of the gauge set measures pressure only. It is calibrated in pounds per square inch. Like the compound gauge previously described, it may have scales which convert the pressure readings to the relative temperatures in the condenser for Refrigerant-12, R-22 and R-502.

High-side pressure also may be referred to as **discharge** or **head** pressure.

The control valve for the high-pressure side is a hand valve. It is located below the pressure gauge, and opens or closes the high-pressure hose to the service hose. It is used when the system is being discharged. At no time does it affect pressure between the high-pressure side hose and the gauge.

WARNING: DO NOT OPEN THE HIGH-PRESSURE SIDE HAND VALVE WHEN THE COMPRESSOR IS RUNNING AND A REFRIGERANT-12 CAN OR TANK IS ATTACHED TO THE SERVICE HOSE. HIGH-DISCHARGE PRESSURES CAN BURST THE REFRIGERANT CONTAINER.

SERVICE HOSES

Service hoses to the vacuum pump and Refrigerant-12 supply may be attached to the manifold center connection.

Prior to performing any testing be sure that the vacuum pump refrigerant container hand valves are fully closed.

CONNECTING THE GAUGE SET

The following procedure should be used for connecting and disconnecting the manifold gauge set **test hoses.** Be sure to observe all safety precautions listed in the appropriate shop manual when performing this operation.

1. Remove the **protector caps** from the compressor service gauge ports or valve stems (Fig. 95).

NOTE: Schrader valves on service ports MUST have a screw-on protector cap to cover and seal the valve when gauges or charging hoses are not connected to it. Failure to reinstall the caps after system service can result in damage to the Schrader valves and allow refrigerant leakage. These service valve caps should be installed finger-tight. Over-tightening the caps can cause them to distort and create refrigerant leakage.

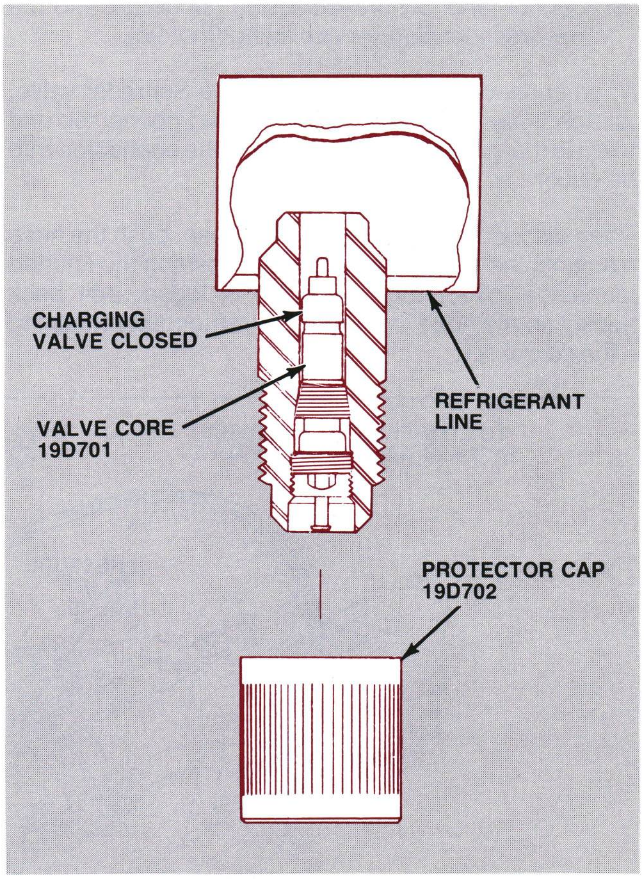


Figure 95 — Service Access Gauge Port Valve Protector Cap

2. Make sure that the manifold gauge hand valves are closed (turned clockwise, all the way in) and that the hose connected to the **service fitting** at the center of the manifold is either capped or connected to the storage fitting on the manifold.

3. Connect the high-pressure side gauge hose to the high-pressure side service fitting (Figs. 96 and 97). Use the correct adapter.

   These adapters contain a Schrader-type valve core to prevent accidental discharge of refrigerant if the service hose is inadvertently disconnected from the adapter while the system is pressurized.

4. Purge the test hoses. Open the hand valve on the high-pressure side of the manifold one turn. "Crack" the low-pressure side hand valve for three seconds (refrigerant vapor will hiss from the low-pressure hose). Then, close both hand valves.

5. Connect the low-pressure side gauge hose to the low-pressure side service fitting (Fig. 96).

When connecting the gauge set to the Schrader valve, pull the hose to the rear of the knurled connector, and hold it in that position while tightening the connector onto the outlet.

When disconnecting the gauge set hose, push the hose in against the service outlet while loosening the knurled connector. When the connector is loose, pull back quickly on the hose to release the refrigerant remaining in the gauge set.

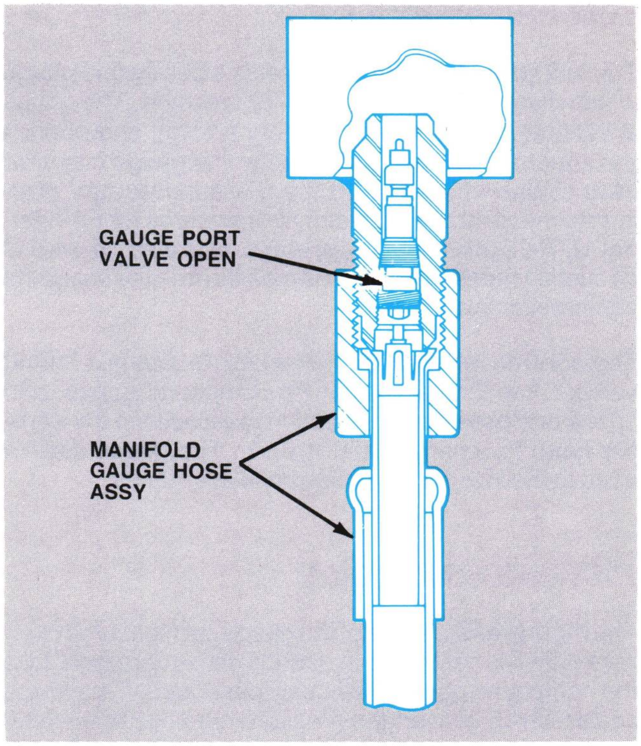


Figure 97 — Gauge Set Hose Assembly Positioning

CAUTION: Keep the hose directed AWAY from the face, hands and drive belts when making the disconnection.

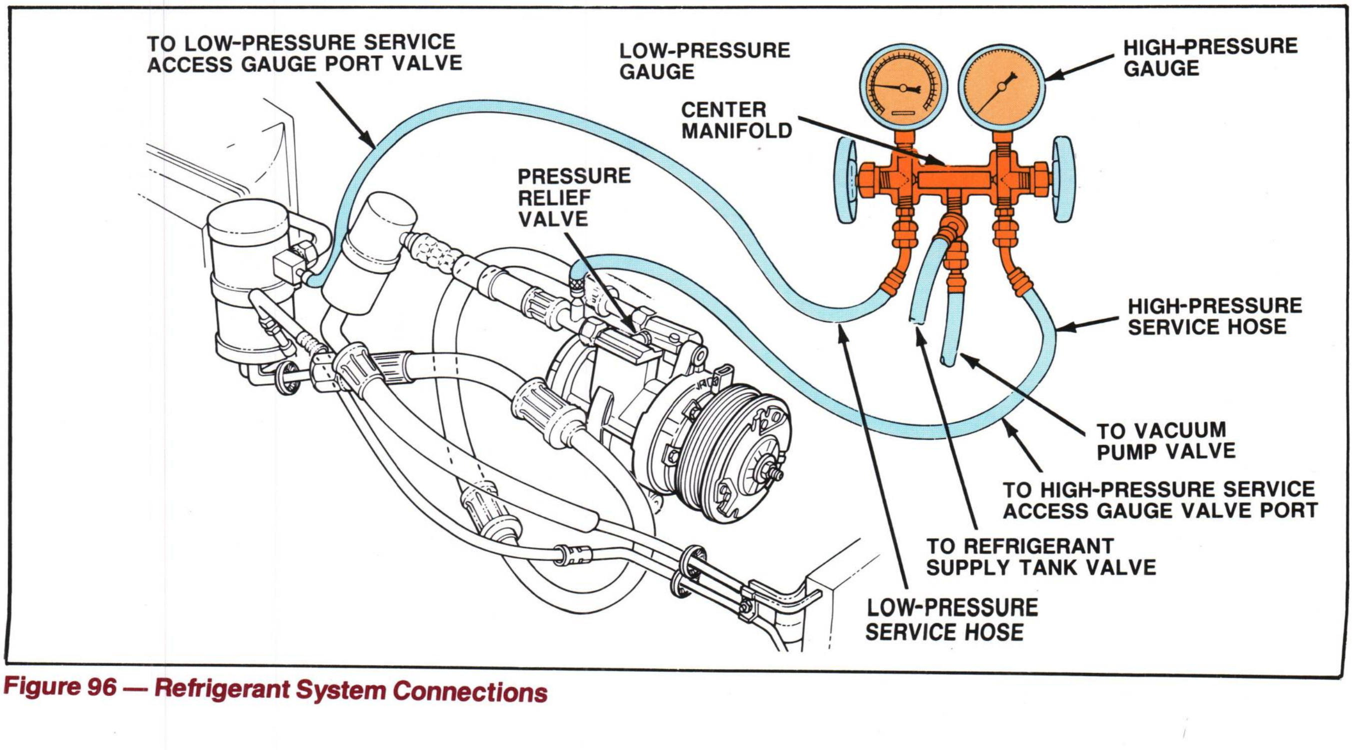


Figure 96 — Refrigerant System Connections

System Discharging (Typical)

Discharge the refrigerant from the system before replacing any system component except the clutch cycling pressure switch.

1. Ensure that the manifold gauge set valves are turned all the way to the right, then attach the manifold gauge set as outlined.
2. Ensure that the center hose connection at the manifold gauge set is tight.
3. Place the open end of the center hose into a garage exhaust outlet.
4. Open the low-pressure valve of the manifold gauge set slightly, and let the refrigerant discharge from the system slowly.
5. When the system is nearly discharged, open the high-pressure gauge valve . Do so slowly to avoid refrigerant oil loss. This will allow any refrigerant trapped in the compressor and high-pressure discharge line to discharge.
6. As soon as the system is completely discharged, close both the high-and low-pressure valves to prevent moisture from entering the system.

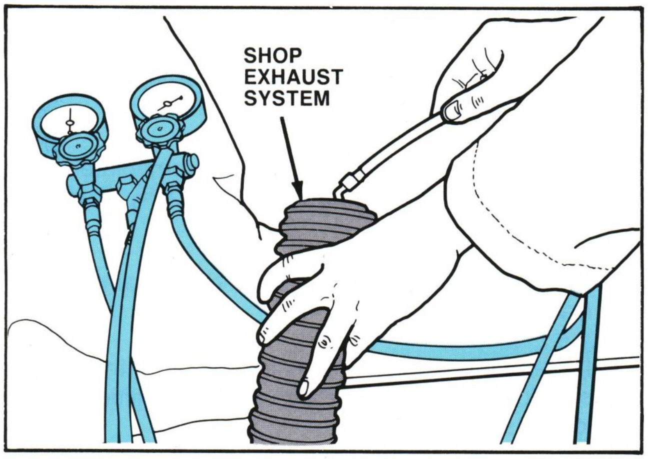


Figure 98 — Discharging the System

System Charging (Typical)

1. With the manifold gauge set valves closed to the center hose, disconnect the vacuum pump from the manifold gauge set.
2. Connect the center hose of the manifold gauge set to a refrigerant charging cylinder. If a charging station is used, follow the instructions of the manufacturer.
3. Loosen the center hose at the manifold gauge set and open the refrigerant charging cylinder valve. Allow refrigerant to escape to purge air and moisture from the center hose. Then, tighten the center hose connection at the manifold gauge set.
4. Disconnect the wire harness snap-lock connector from the clutch cycling pressure switch. Install a jumper wire across the two terminals of the connector if necessary.
5. Open the manifold gauge set low-pressure side valve to allow refrigerant to enter system. Keep refrigerant cylinder in an upright position if the vehicle low-pressure service gauge port is not on the suction accumulator/drier or suction accumulator fitting.
6. When no more refrigerant is being drawn into the system, start the engine and move the air function control lever to the A/C position, and the blower switch to HIGH. This action will draw the remaining refrigerant into the system.

   Continue to add refrigerant to the system until the specified weight of Refrigerant-12 is in the system. Then, close the manifold gauge set low-pressure valve and the refrigerant supply valve.
7. Remove the jumper wire from the clutch cycling pressure switch snap-lock connector if necessary. Attach the connector to the pressure switch.
8. Operate the system until the pressures stabilize to verify normal operation and system pressures.
9. In high ambient temperatures, it may be necessary to operate a high volume fan positioned to blow air through the radiator and condenser to aid in cooling the engine and prevent excessive refrigerant system pressures.
10. When charging is completed and system operating pressures are normal, disconnect the manifold gauge set from the vehicle. Install protective caps on the service gauge port valves.

Charging From Small Containers

The refrigerant charge level of currently used A/C systems is critical to optimum performance. An overcharged or under-charged condition will adversely affect performance. Using small cans to charge these systems is not recommended because the charge level cannot be accurately controlled. Use a charging cylinder or charging station to add refrigerant to the A/C system. No other charging methods are recommended.

HYDRAULIC MEASURING DEVICES

Hydraulic measuring devices measure the pressure and specific gravity of fluids under various conditions. Some examples of hydraulic measuring device usage include determining coolant strength (anti-freeze tester), battery charge (hydrometer), transmission operating pressure (TV pressure gauge set), power steering pressure (power steering pressure tester) and diesel fuel quality (cetane tester).

Hydraulic measuring devices are usually calibrated in two systems: psi (pounds per square inch) and kPa (kilopascals). To explain how the two systems relate to each other, convert a known pressure into its equivalent in both systems. For example, 100 psi equals 689.5 kPa (100 psi × 6.895 conversion factor equals 689.5 kPa). In other words, one pound per square inch of pressure (psi) equals about seven kilopascals (kPa).

When you test high-pressure hydraulic systems, you must be extremely careful to avoid hazards of all types: Battery acid can damage automotive finishes, your skin and eyes; all flammable liquids must be handled with caution; fluids under high-pressure can penetrate your skin (even if you are wearing gloves) and pose a serious health hazard.

NOTE: Always refer to the appropriate shop manual before performing service or diagnosis procedures. Always observe the safety precautions listed in the shop manual.

NOTE: Check your instruments regularly against known good equipment to ensure that they are operating properly and capable of accurate measurement.

BATTERY HYDROMETER

The battery hydrometer tests the state of charge on batteries which have removable cell caps. It consists of a squeeze bulb, sight glass and suction tube for drawing electrolyte samples into the sight glass (Fig. 99). Most hydrometers are equipped with a thermometer.

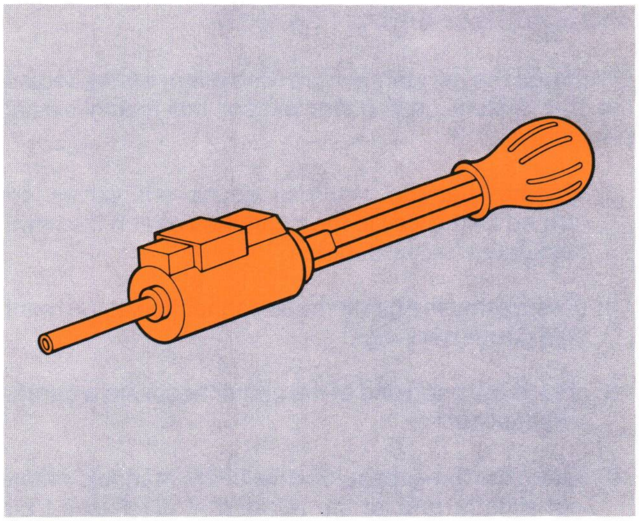


Figure 99 — Typical Battery Hydrometer

The hydrometer operates by measuring the specific gravity of the battery acid. In other words, the hydrometer compares the weight of a given volume of battery acid with the same volume of water. The comparison of the weight of these two fluids is displayed as a reading on the sight glass.

The hydrometer is a useful device if it is used within its limitations, which are as follows:

- It cannot be used if the electrolyte level is too low to draw a sample.
- If you draw an electrolyte sample immediately after adding water, the hydrometer will display an inaccurate reading.
- The hydrometer cannot be used on maintenance-free batteries.
- If the hydrometer readings indicate that the battery should be replaced, verify battery condition with a load test if possible.

HYDRAULIC MEASURING DEVICES

Checking Specific Gravity (Typical)

To measure the specific gravity of battery electrolyte, perform the following procedures:

1. Remove the battery cell caps and set them aside.
2. Squeeze the bulb on the hydrometer, and insert the suction tube into the battery electrolyte (Fig. 100).
3. Release the pressure on the bulb, and draw enough electrolyte into the sight glass to obtain a reading.
4. Compare the reading with the specific gravity chart (Fig. 101) to determine the battery charge.
5. Squeeze the bulb to return the electrolyte sample to the cell from which it was taken.
6. EXAMPLE: If the hydrometer readings for all cells are similar, and the readings are 1.225 or higher, the battery is O.K. and about 75 percent charged. If the readings are the same but below 1.225, charge and retest the battery.

SPECIFIC GRAVITY	% CHARGED
1.100	DISCHARGED
1.130	25%
1.170	
1.190	50%
1.210	
1.230	75%
1.250	
1.270	FULL CHARGE

Figure 101 — Specific Gravity and Charge Reference Chart

READINGS	CONDITION
1.225 OR HIGHER	SERVICEABLE
BELOW 1.225	RECHARGE AND RETEST
50 POINT VARIATION BETWEEN CELLS	REPLACE

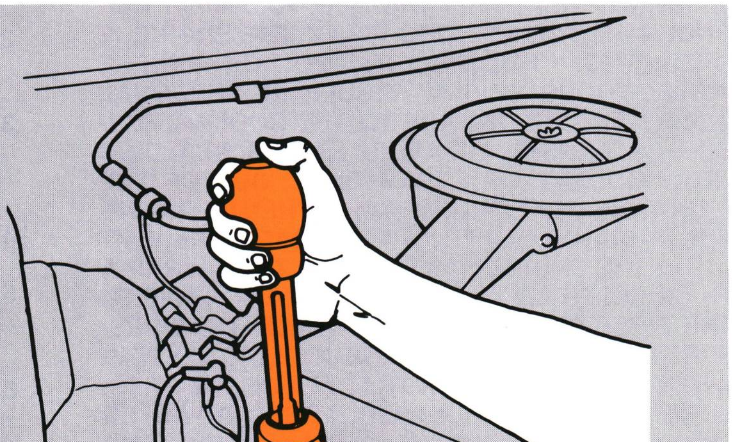


Figure 100 — Using the Hydrometer

ANTI-FREEZE TESTER

The anti-freeze tester (Fig. 102) measures the concentration of the coolant mixture. To provide maximum protection from freezing and overheating, a 50/50 (approximately) coolant/water mixture should be maintained at all times. Coolant mixtures that are too weak or too strong do not provide adequate protection against freezing and overheating in all conditions.

If the coolant mixture is too weak (30% or less), the coolant will freeze at about 4°F (-16°C). Weak coolant mixtures also cause engine corrosion and overheating.

If the coolant mixture is too strong, poor protection against freezing can result. Pure (undiluted) anti-freeze turns into a gel somewhat below the temperature that water freezes. It is very hard for a water pump to circulate the gel; damage can result from starting an engine under these conditions.

NOTE: Some testers of this type can also be used to check the specific gravity of battery electrolyte.

WARNING: NEVER REMOVE THE RADIATOR CAP UNDER ANY CONDITIONS WHILE THE ENGINE IS OPERATING. FAILURE TO FOLLOW THESE INSTRUCTIONS COULD RESULT IN PERSONAL INJURY AND/OR DAMAGE TO THE COOLING SYSTEM OR ENGINE. TO AVOID HAVING SCALDING HOT COOLANT OR STEAM BLOW OUT OF THE RADIATOR, USE EXTREME CARE WHEN REMOVING THE RADIATOR CAP FROM A HOT RADIATOR. WAIT UNTIL THE ENGINE HAS COOLED, THEN WRAP A THICK CLOTH AROUND THE CAP, AND TURN IT TO THE FIRST STOP. STEP BACK WHILE THE PRESSURE IS RELEASED FROM THE COOLING SYSTEM. WHEN YOU ARE CERTAIN THAT ALL OF THE PRESSURE HAS BEEN RELEASED, PRESS DOWN ON THE CAP (STILL USING CLOTH), TURN AND REMOVE.

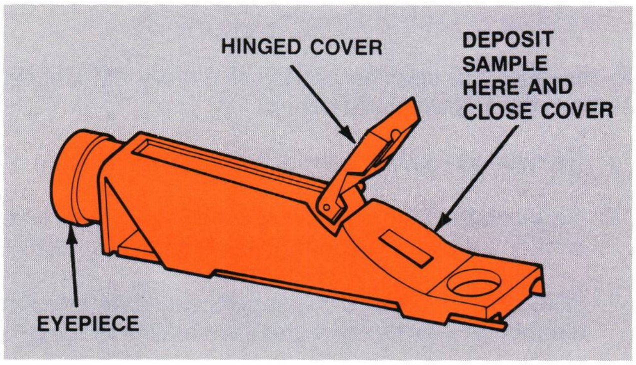


Figure 102 — Typical Anti-Freeze Tester

Coolant Strength Testing (Typical)

To test coolant concentration, perform the following procedure:

1. Refer to the applicable shop manual. Follow all procedures, and observe all safety precautions. Perform this procedure on a cold engine.
2. Using an eyedropper or other suitable tool, obtain a small sample of the engine coolant from the radiator.
3. Lift the hinged cover (Fig. 102) on the anti-freeze tester, and place a few drops of coolant mixture into the slotted opening.
4. Close the hinged cover over the coolant sample.
5. Hold the tester in front of a light source, and look into the eyepiece.
6. A direct reading of anti-freeze protection will be displayed in degrees.
7. Adjust coolant mixture strength as necessary.

RADIATOR AND HEATER CORE PRESSURE TESTER

The radiator and heater core pressure tester tests cooling system components at room temperature. By testing the system at room temperature, it can be checked quickly and safely. The hazards of handling scalding hot components and liquids are avoided.

The tester consists of a pump, gauge, flexible hose, and various adapters for testing radiators, heater cores and radiator pressure caps (Figs. 103 and 104). To use the tester, install the adapter(s) onto the component, and pump the specified pressure into the component using the hand pump. Then, observe the pressure gauge, and note any pressure drop (leakage).

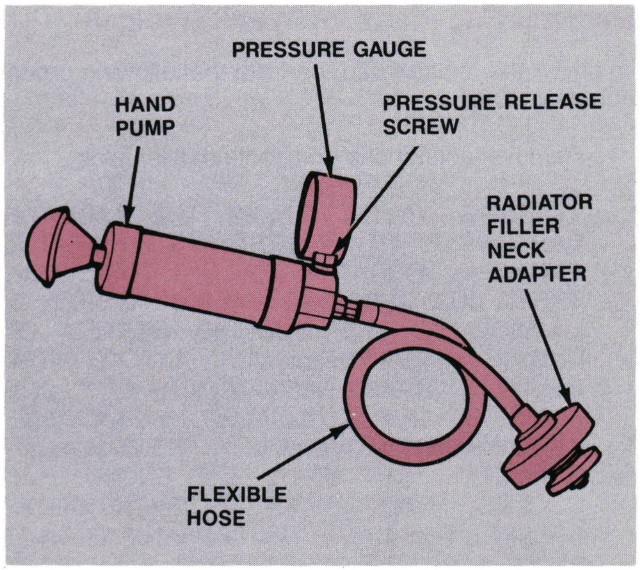


Figure 103 — Typical Cooling System and Radiator Cap Pressure Tester

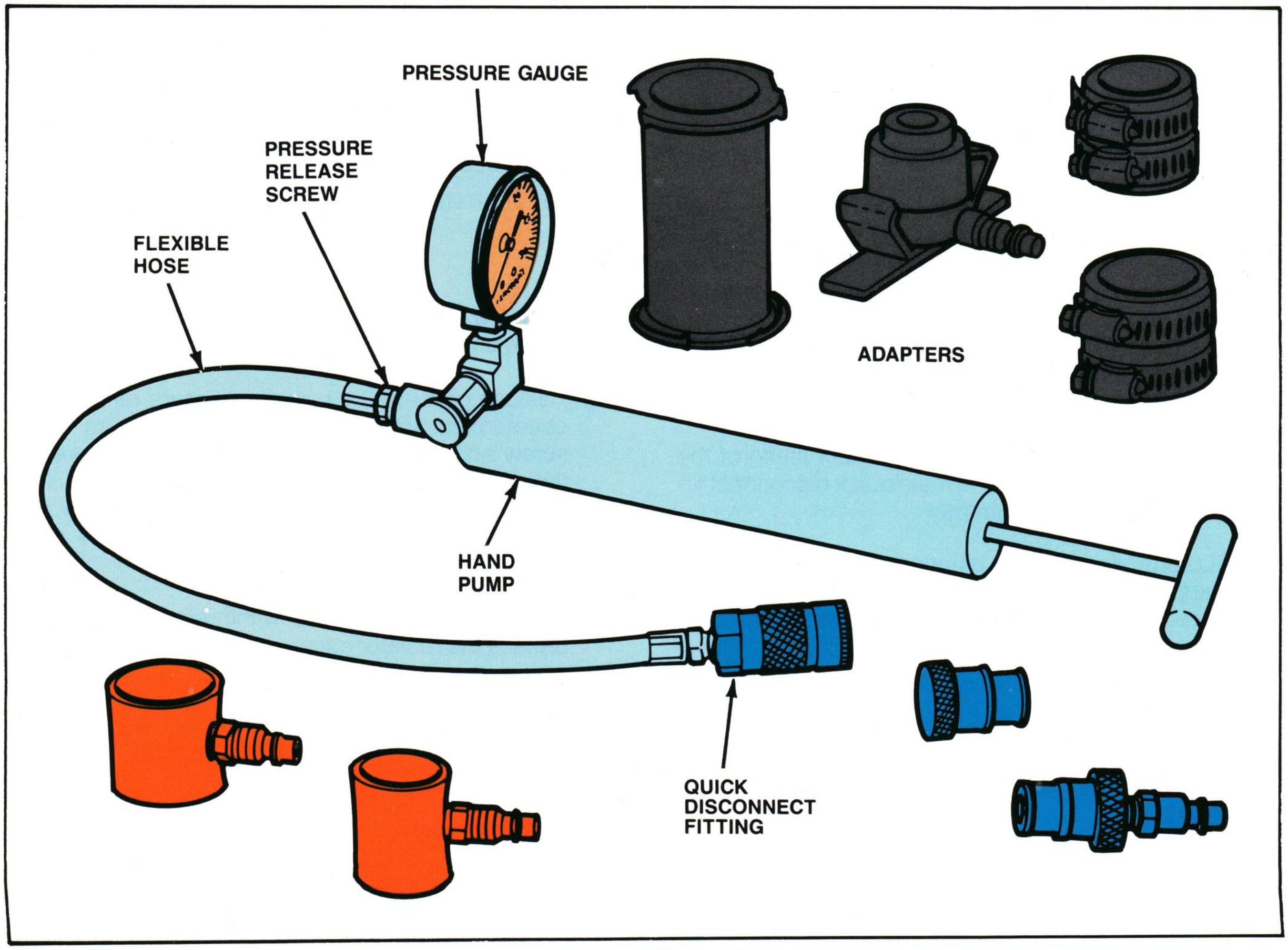


Figure 104 — Typical Radiator and Heater Core Pressure Tester Radiator Cap

Radiator Cap Pressure Check (Typical)

To check the radiator cap, perform the following procedure (Fig. 105):

1. Remove radiator cap from radiator filler neck.

   WARNING: NEVER REMOVE THE RADIATOR CAP UNDER ANY CONDITIONS WHILE THE ENGINE IS OPERATING. FAILURE TO FOLLOW THESE INSTRUCTIONS COULD RESULT IN DAMAGE TO THE COOLING SYSTEM OR ENGINE AND/OR PERSONAL INJURY. TO AVOID HAVING SCALDING HOT COOLANT OR STEAM BLOW OUT OF THE RADIATOR, USE EXTREME CARE WHEN REMOVING THE CAP FROM A HOT RADIATOR. WAIT UNTIL THE ENGINE HAS COOLED, THEN WRAP A THICK CLOTH AROUND THE RADIATOR CAP AND TURN IT SLOWLY TO THE FIRST STOP. STEP BACK WHILE THE PRESSURE IS RELEASED FROM THE COOLING SYSTEM. WHEN CERTAIN ALL THE PRESSURE HAS BEEN RELEASED, PRESS DOWN ON THE CAP (STILL WITH A CLOTH), TURN AND REMOVE.

2. Use water to clean the cap in the area of the rubber seal and vacuum relief valve. Immerse the radiator cap in water and install the radiator cap pressure test adapter from the pressure tester.

3. Immerse the filler neck seal in water and install it into the filler neck adapter. Then, install the filler neck adapter with seal on the open end of the radiator cap pressure test adapter.

   NOTE: The filler neck seal is reversible so it may be used on either end of radiator cap pressure test adapter.

4. Connect the female quick disconnect fitting of the pressure test pump to the male quick disconnect fitting of the filler neck adapter.

5. SLOWLY depress the plunger of the pressure test pump until the pressure gauge reading stops increasing. Note the highest pressure reading obtained.

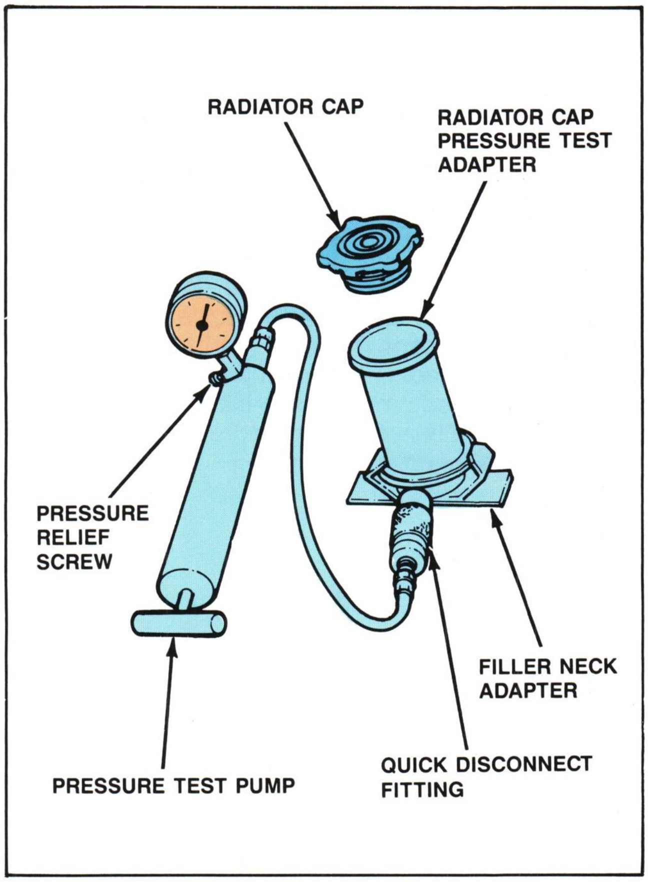


Figure 105 — Radiator Cap Pressure Testing

   NOTE: If the pump plunger is depressed too fast, an erroneous pressure reading will result.

6. Release pressure by turning pressure relief screw counterclockwise. Then, tighten pressure relief screw and repeat Step 5 (at least twice) to ensure that the pressure test reading is repeatable within acceptable gauge reading limits of the radiator cap and is not erratic. Refer to the appropriate shop manual for specifications.

7. If gauge readings are not within acceptable limits, replace the radiator cap.

LOW-PRESSURE FUEL PRESSURE GAUGE

The low-pressure fuel pressure gauge (Fig. 106) is used to check fuel pump and fuel pressure regulator operation. Various adapters allow the gauge to be connected into the fuel system for diagnostic procedures.

Most fuel pump and fuel pressure regulator malfunctions result in reduced fuel supply to the engine. These conditions usually result in reduced engine performance. The fuel system component pressure testing procedures allow diagnosis and isolation of problems.

NOTE: Perform all fuel system service and diagnosis procedures with caution. Refer to the applicable shop manual for procedures and specifications.

NOTE: If no pressure is detected in the fuel lines during the test procedure, do not allow the fuel pump to be powered for more than three minutes to avoid overheating the fuel pump.

NOTE: It is only necessary to test low-pressure fuel pumps if noise or low flow conditions exist.

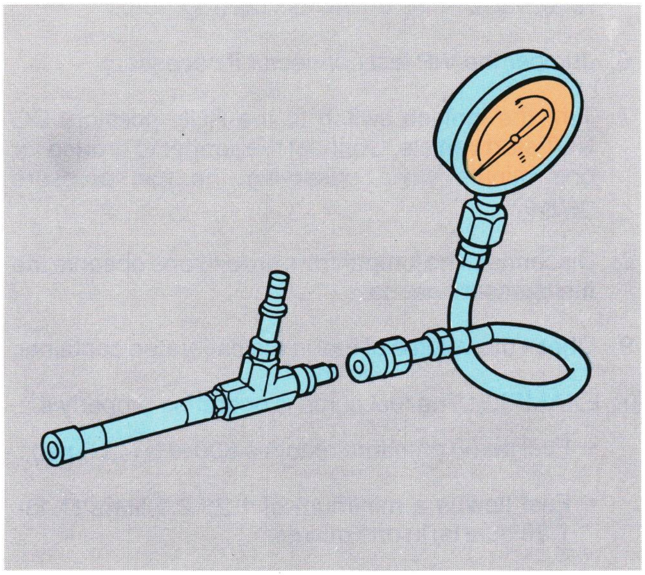


Figure 106 — Low-Pressure Fuel Pressure Gauge

The pressure regulator is part of the fuel charging main body and is located near the rear of the air horn. It compensates for the effects of supply line pressure drops. It is designed so that it is not sensitive to back pressure in the return line to the tank.

One function of the pressure regulator is to maintain fuel supply pressure after engine and fuel pump shutdown. The regulator functions as a downstream check valve and traps the fuel between itself and the fuel pump. Maintaining fuel pressure after engine shutdown reduces fuel line vapor formation. It allows for rapid restarts and for stable idle operation. The regulated pressure is typically 100 kPa (14.5 psi). However, this value may vary from unit to unit. Pressure is adjusted at the factory to compensate for differences in fuel flow among injectors.

Fuel Pressure Regulator Checking (Typical)

To check the operation of the fuel pressure regulator, perform the following procedure:

NOTE: The fuel pressure regulator is factory adjusted. Do not attempt to reset fuel pressure by adjusting it.

Refer to the Engine/Emissions Diagnosis manual before performing any service operations.

1. Disconnect the electrical connection to the inertia switch if necessary.
2. Crank the engine for 15 seconds to reduce fuel system pressure.

   CAUTION: Use care to prevent combustion from fuel spillage.
3. Disconnect the fuel supply at the fuel filter. Connect the adapter into the fuel line. Connect the fuel gauge to the adapter.
4. Connect the inertia switch if disconnected.
5. Start the engine and check the fuel system pressure. Then, accelerate the engine. Pressure should remain stable throughout acceleration.

Pressure Check Gauge Removal (Typical)

1. Disconnect the electrical connection to the inertia switch.
2. Crank the engine for 15 seconds.
3. Remove the gauge.
4. Install the original fuel line.
5. Connect the inertia switch.
6. Crank the engine and check for leaks.

EFI/CFI PRESSURE GAUGE

The EFI/CFI pressure gauge (Fig. 107) measures fuel pump and fuel pressure regulator operation. Various adapters allow the gauge to be connected into the fuel system for diagnostic procedures. This gauge is capable of measuring much higher pressures than the low-pressure fuel pressure gauge.

Most fuel pump and fuel pressure regulator malfunctions result in reduced fuel supply to the engine. These conditions usually result in reduced engine performance. The fuel system component pressure testing procedures allow diagnosis and isolation of problems.

NOTE: If no pressure is detected in the fuel lines during the test procedure, do not allow the fuel pump to be powered for more than three minutes to avoid overheating the fuel pump.

NOTE: Perform all fuel system service and diagnosis procedures with caution. Refer to the applicable shop manual for procedures and specifications.

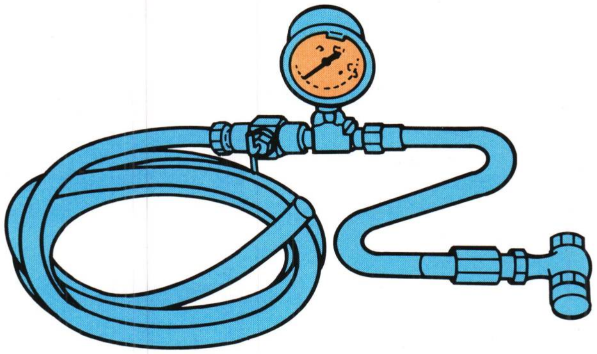


Figure 107 — Typical EFI/CFI Pressure Gauge

Fuel Pump Flow/Pressure Tests (Typical)

To check fuel pump operation perform the following procedure:

1. Disconnect the electrical connector at the inertia switch.
2. Crank the vehicle for a minimum of 15 seconds to reduce the fuel pressure in the lines.
3. Disconnect the fuel return line at the pressure regulator. Use care to avoid fuel spillage.

   CAUTION: Use care to prevent combustion from fuel spillage.

   CAUTION: The fuel system contains pressurized fuel after vehicle is shut down and maintains this pressure for a long period of time.

4. Connect the hose from the fuel return fitting to a calibrated container of at least two liters (two quarts).
5. Attach the EFI/CFI fuel pressure gauge to the Schrader valve fitting on the fuel rail (Fig. 108).
6. Jumper the VIP test connector if necessary.
7. Turn the ignition switch to the RUN position. DO NOT start vehicle. Connect the jumper to ground for one minute while observing the fuel pressure gauge.
8. Disconnect the jumper from ground and observe the fuel pressure gauge.
9. Check the volume of fuel in the calibrated container.
10. EXAMPLE: The fuel pump is operating properly if:
    - Fuel pump pressure reaches 300 kPa (43.5 psi).
    - Fuel flow is a minimum of 1.25-2.9 liters (1.18-1.96 quarts) in one minute.
    - Fuel pressure remains at a minimum of 207 kPa (30 psi) immediately after shutdown.

11. If all three conditions are met, the fuel pump is operating properly. Check for engine and electrical problems if necessary.

12. If the pressure condition is met, but the flow condition is not, check for blocked filters and fuel supply lines. After correcting any blockages, recheck. If the flow condition is still not met, perform the fuel pump electrical diagnosis procedures outlined in the appropriate shop manual.

13. If both the pressure and flow conditions are met, but the pressure will not maintain after de-energization, check for leaking injectors or pressure regulator. If the injectors and the regulator check OK, replace the fuel pump-sender assembly.

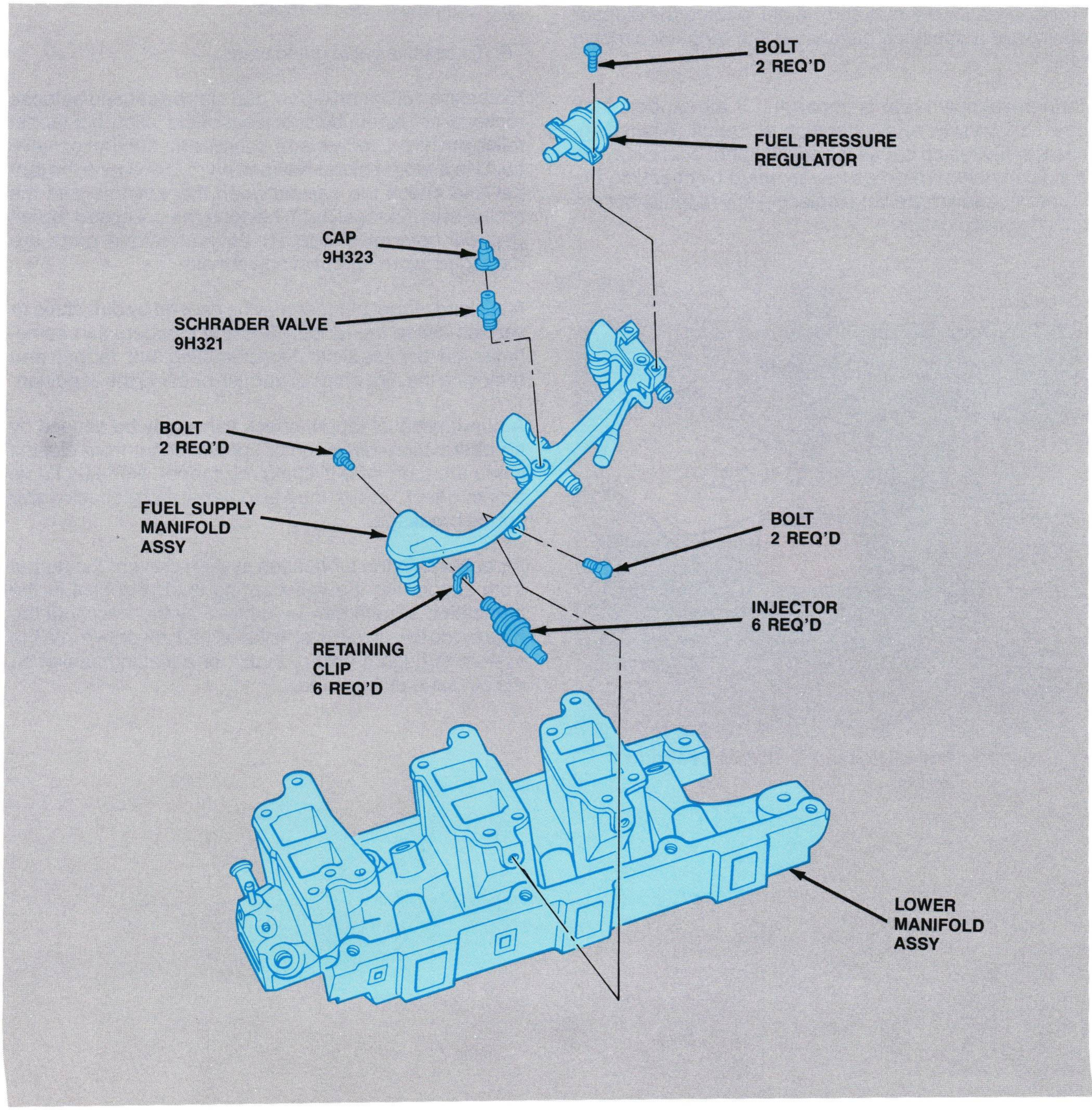


Figure 108 — Typical Fuel Supply Manifold Showing Schrader Valve

HYDRAULIC TAPPET LEAKDOWN TESTER

The hydraulic tappet leakdown tester (Fig. 109) checks the condition of hydraulic tappets. Tappet condition is measured by the amount of time it takes a 50 lb. weight to compress the tappet plunger a specified distance.

Tappet leakdown rate is tested as follows: the tappet is first filled with special testing fluid, then sealed with a steel ball. A ram with a weight attached is then made to bear on the steel ball (located in the pushrod cup). The time it takes for the ram and weight to force the plunger downward a specified distance is the tappet leakdown rate.

Tappet leakdown rate is important; if the tappets leak down too quickly, noisy operation will result. When diagnosis indicates no cause for noisy tappet operation, the condition can sometimes be remedied by checking the tappet leakdown rate, and replacing any tappets that are outside specification.

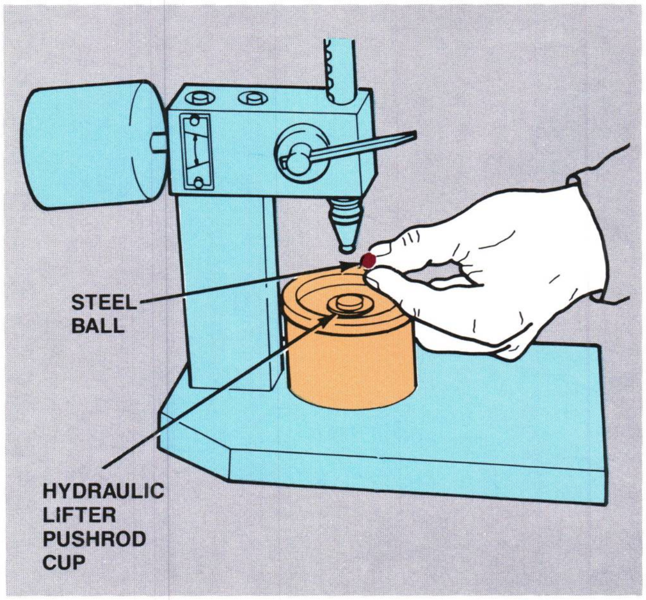


Figure 109 — Typical Hydraulic Tappet Leakdown Tester

Hydraulic tappet noise may be caused by any of the following:

1. Excessive collapsed tappet gap
2. Sticking tappet plunger
3. Tappet check valve not functioning properly
4. Air in lubrication system
5. Leakdown rate too rapid
6. Excessive valve guide wear

Excessive collapsed tappet gap may be caused by loose rocker arm fulcrum bolts or wear of the following: tappet roller, push rod, rocker arm, rocker arm fulcrum or valve tip. Use a tappet bleed-down wrench to collapse the tappet and check the gap between the valve tip and the rocker arm if necessary. Checking the collapsed tappet gap will determine whether any valve train parts are damaged, worn, or out of adjustment.

A sticking tappet plunger may be caused by dirt, chips or varnish inside the tappet. Sticking plungers can sometimes be serviced by disassembling the tappet and removing the dirt, chips or varnish causing the condition.

A non-functional tappet check valve may be caused by an obstruction (dirt or chips) preventing it from closing when the cam lobe is lifting the tappet. Non-functional tappet check valves may also result from check valve spring breakage.

Air bubbles in the lubrication system prevent the tappet from supporting the valve spring load. Bubbles in the lubrication system may be caused by the following: too high or too low an oil level in the oil pan, air drawn into the system through a hole or crack, or a leaking gasket on the oil pump pickup tube.

Checking Tappet Leakdown (Typical)

To check tappet leakdown, perform the following procedure:

1. Disassemble and clean the tappet to remove all traces of engine oil.

   NOTE: Do not mix parts from different tappets. Parts are select-fitted and are NOT interchangeable.

   NOTE: Tappets cannot be checked with engine oil in them. Only testing fluid can be used.

2. Place the tappet in the tester, with the plunger facing upward. Pour hydraulic tappet tester fluid into the cup until the tappet assembly is covered. The fluid can be purchased from the manufacturer of the tester.

   NOTE: Using kerosene or any other fluid will not provide an accurate test.

3. Place the 5/16-inch steel ball provided with tester into the plunger cap.
4. Adjust ram length so that the pointer is 1.59mm (1/16-inch) below the starting mark when the ram contacts the tappet plunger, to permit timing as the pointer passes the Start Timing mark (Fig. 110). Use the center mark on the pointer scale as the Stop Timing point instead of the original Stop Timing mark at the top of the scale.
5. Work the tappet plunger up and down until the tappet fills with fluid and all traces of air bubbles have disappeared.
6. Allow the ram and weight to force the tappet plunger downward. Measure the exact time it takes for the pointer to travel from the Start Timing to the Stop Timing marks of the tester.
7. A satisfactory tappet must have a leakdown rate (time in seconds) within the minimum and the maximum specified limits.
8. If the tappet leakdown rate is not within specifications, replace it with a new tappet. It is not necessary to disassemble and clean the new tappets before testing, because the new tappets contain test fluid.
9. Remove the fluid from the cup and bleed the fluid from the tappet by working its plunger up and down. This step will ease depression of the tappet plungers when checking the valve clearance.

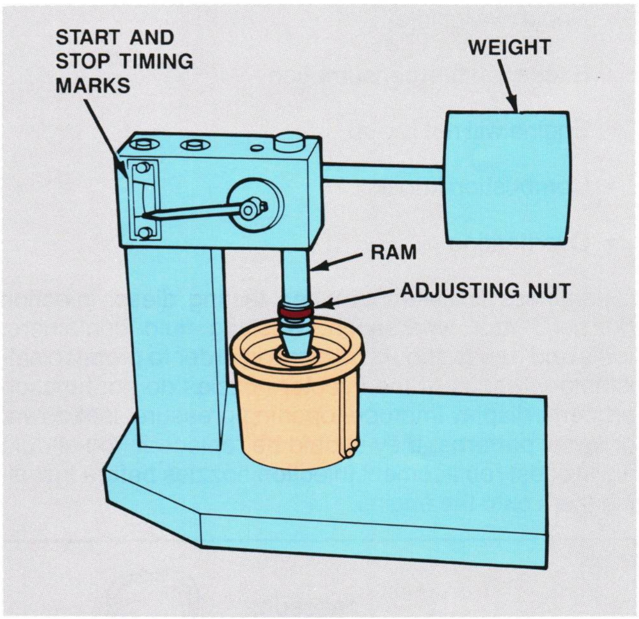


Figure 110 — Adjusting the Ram Length

DIESEL INJECTION NOZZLE TESTER

The diesel injection nozzle tester checks the condition of the nozzles. It can provide valuable information about nozzle condition when it is used to bench test the nozzles. It consists of a reservoir filled with special calibration fluid, a high-pressure pump, and the adapters necessary to attach a pressurized fluid line to a nozzle (Fig. 111).

Diesel injection nozzles seldom require service if the engine operates on clean fuel, has good combustion, and operates within specified temperature ranges. However, nozzle trouble is usually indicated by one or more of the following:

- Black exhaust smoke
- Power loss
- Rough warm idle
- Excessive fuel consumption
- Engine will not rev up
- Combustion knock
- Overheating

Cleanliness is essential when testing diesel injection nozzles. Your workbench, washing fluid containers, tools and hands should be clean in order to produce satisfactory results. If the injector nozzles do not function properly, display improper opening pressure, leakdown, or spray patterns, they should be replaced. You should always test replacement injection nozzles before installing them onto the engine.

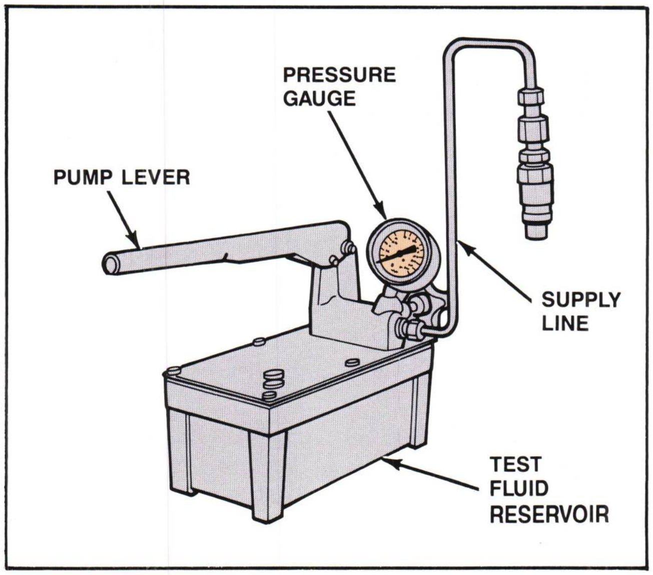


Figure 111 — Typical Injection Nozzle Tester

Injector Nozzle Testing (Typical)

To test a diesel injector nozzle, perform the following procedure (Fig. 112):

1. Prepare the stand for making tests. Place a container partially filled with shop cloths beneath the outlet pipe to catch nozzle output spray. Fill the stand reservoir with clean calibration fluid. Open the tester valve until solid fuel (no air bubbles) flows from the end of the outlet pipe. Close the tester valve.

   NOTE: Test injector nozzles using SAE approved calibration oil 208629, SAE J967D, or ISO 4113 fluid, rather than diesel fuel.

2. Install the proper test adapter onto the injector nozzle test stand.
3. Connect the nozzle to the test stand. Use care to avoid cross-threading the nozzle. Tighten the connector nut securely with a wrench.

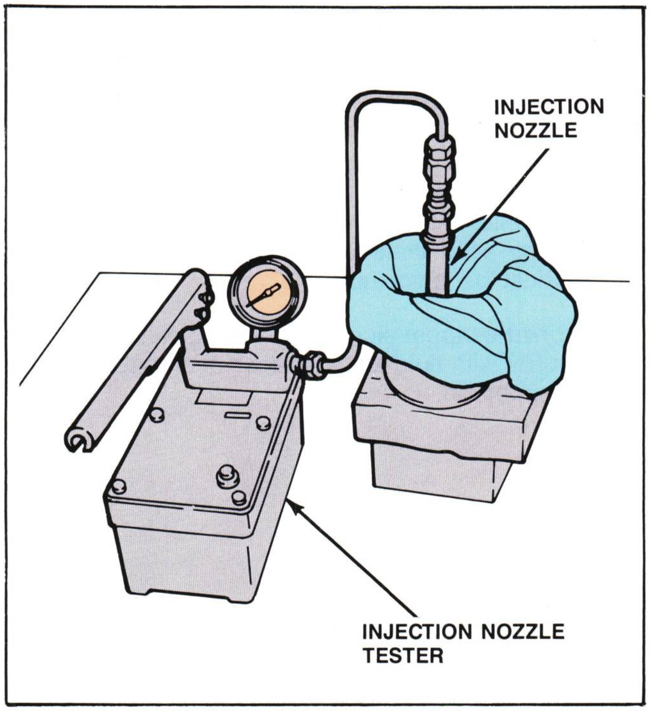


Figure 112 — Testing the Injector Nozzle on the Bench

WARNING: ALWAYS WEAR APPROVED SAFETY GLASSES WHEN OPERATING THE TESTER. VOLATILE LIQUIDS CAN BE EXTREMELY FLAMMABLE WHEN VAPORIZED. AVOID ANY CONDITIONS (SPARKS, OPEN FLAMES, LIT CIGARETTES, ETC.)

WHICH MIGHT IGNITE THE FLUID USED DURING THE TEST PROCEDURE. ENSURE THAT THE INJECTOR IS MOUNTED ON THE TESTER SO THAT THE SPRAY IS DIRECTED AWAY FROM THE OPERATOR AND ANY OTHER PERSONS. THE ONLY LIQUID APPROVED FOR USE IN THIS TESTER IS SAE CALIBRATION NO. 208629 OR EQUIVALENT CALIBRATION FLUID (SAE J967D OR ISO 4113).

WHEN A NOZZLE IS BEING TESTED OR IS IN OPERATION, KEEP HANDS AND OTHER PARTS OF THE BODY AWAY FROM THE SPRAYING NOZZLE. THE LIQUID SPRAY LEAVES THE NOZZLE TIP WITH SUFFICIENT FORCE TO PENETRATE THE SKIN AND CAUSE SERIOUS INJURY. THE NOZZLE TIP SHOULD BE ENCLOSED IN A TRANSPARENT RECEPTACLE IF AVAILABLE.

4. Bleed air from the nozzle as follows: Open the tester valve and operate tester handle to expel (bleed) air from the injector nozzle. Test fluid should spray from the spray holes in the nozzle tip. If the nozzle is blocked or the needle is jammed, replace the injector. Replacement injectors should be tested before assembly to the engine.

   NOTE: Conduct opening pressure, tip leakage and spray pattern tests separately.

   Do not attempt to evaluate more than one test step or result at a time.

5. **Check nozzle opening pressure** by pumping the injector nozzle tester and observing the pressure at which the needle valve lifts and fuel is ejected from the nozzle tip. Nozzle opening pressure must meet specifications, or the nozzle should be replaced.

6. **Check the nozzle for tip leakage.** Wipe the nozzle tip dry and operate the tester to specified pressure. This pressure is below the opening pressure of the nozzle. Hold the pressure for specified time. If droplets form on the tip of the injector and fall off, the nozzle should be replaced. Wetness on the tip of the injector is acceptable.

   NOTE: Do not wipe the tip with your fingers, because it tends to draw a small amount of fluid out of the injector giving a false impression of a leak. Use a clean cloth or blotting paper.

7. **Check the spray pattern of the nozzle** by pumping the tester handle rapidly and observing the spray pattern coming from the orifices. Spray must come from each orifice and be similar in size and consistency. The spray should be well atomized and cone shaped as it comes from the injector nozzle (Fig. 113). Follow the manufacturer's recommendations regarding injector replacement.

8. If the injector fails any of the tests, overhaul or replace the injector.

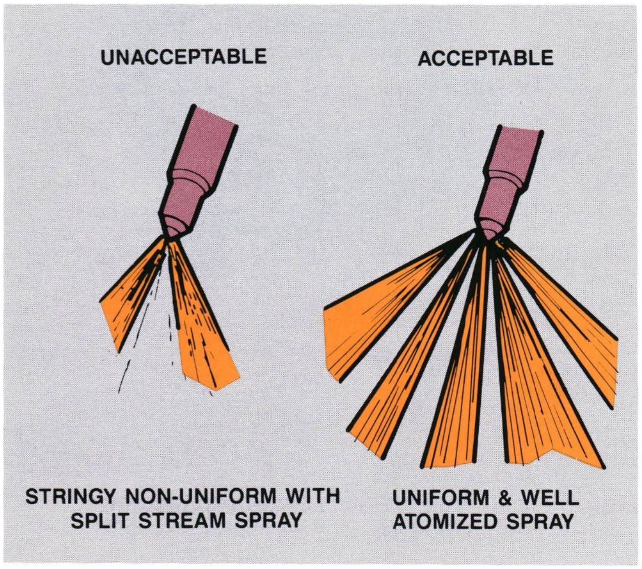

UNACCEPTABLE
ACCEPTABLE
STRINGY NON-UNIFORM WITH SPLIT STREAM SPRAY
UNIFORM & WELL ATOMIZED SPRAY

Figure 113 — Injector Nozzle Spray Patterns (Typical)

POWER STEERING SYSTEM ANALYZER

The power steering system analyzer (Fig. 114) combines a pressure gauge and flowmeter. It is used to diagnose and pinpoint power steering system concerns. The analyzer provides readouts for system back pressure, pump flow, steering gear internal leakage, power steering control valve and cylinder internal leakage. The interpretation of these readouts can determine faulty components or problem areas including hose/fitting restrictions, an inefficient pump cam pack, binding suspension components, faulty gear and relief valve, or faulty control valve and cylinders.

Power steering system analyzers are usually calibrated from 0-2000 psi for automotive use. Medium and heavy truck power steering system analyzers are usually calibrated from 0-3000 psi.

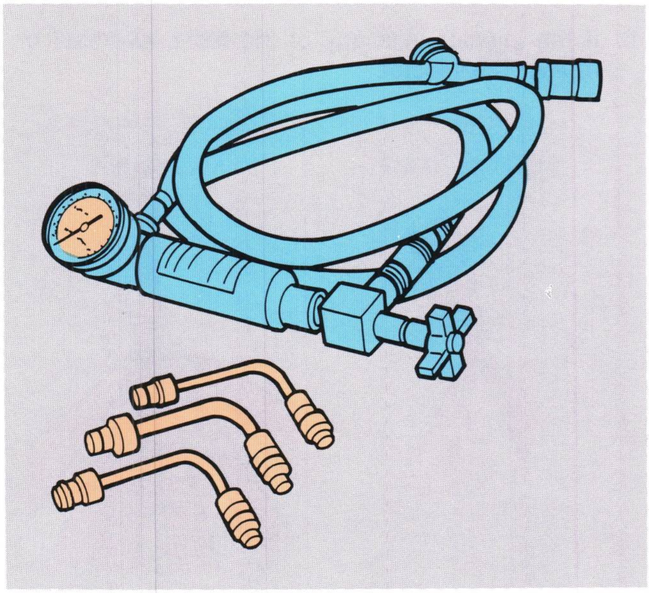


Figure 114 — Typical Power Steering System Analyzer

Power Steering Pump Flow and Pressure Test (Typical)

Before performing the pump flow and pressure test, perform the following checks for conditions which could cause loss of power assist. Any necessary corrective action must be taken.

1. Check the pump reservoir for proper fluid level.
2. Check the tires for correct air pressure.
3. Check the pump belt for proper tension.
4. Check the pump to verify correct model and vehicle application.
5. Check for correct size pulleys on the pump and engine.
6. Check the entire power steering system for damage. Replace parts as necessary.

If the above items are correct and within specifications limits and the loss of assist still exists, test the power steering pump flow and pressure to determine whether the trouble is in the pump or power steering gear.

Necessary Test Equipment

1. Engine tachometer.
2. Thermometer: 0—300°F (-17.8—148.9°C).
3. A power steering system analyzer.
4. Set of adapter fittings.

The test procedure used in conjunction with the power steering system analyzer provides a method for checking the complete power steering system. The analyzer can be used on integral or non-integral power steering systems to determine the cause of hard steering and/or lack of assist problems.

Test Procedure (Typical)

1. To connect the analyzer into the steering system, remove the pressure fitting from the pump and connect it into the appropriate adapter of the analyzer (Fig. 115).
2. Thread the other adapter into the pump.
3. Connect the analyzer to the adapters. Tighten both connections to the specified value.
4. Add power steering fluid to the pump if required. Start the engine, and run it for approximately two minutes **with the idle set to specification.**

5. Record the following:

   a. Flow (gallons/min.) (liters/min.) 172°F ± 5°F (78°C ± 2°C).

   b. Pressure (psi at 172°F ± 5°F [78° ± 2°F]) at idle with the gate valve fully open. (The following figures are typical; refer to specifications for applicable pressures.)

      - If flow is less than 1.6 gallons/min. (6 liters/min.), the pump may require service; however, at this point continue the diagnosis. Check specifications for the flow and relief pressure of the vehicle and engine being tested.

      - If pressure is above 150 psi (1034 kPa), check hoses for restrictions.

6. Partially close the gate valve to build up 740 psi (5100 kPa). Observe and record flow (gallons/min.) (liters/min.) at 172°F ± 5°F (78°C ± 2°C).

   If flow drops to a level lower than the specified minimum, disassemble the pump and replace the cam pack. If the pressure plates are cracked or worn, replace them. Continue with diagnosis.

7. Completely close, and then partially open the gate valve three times. (Do not allow the valve to remain closed for more than five seconds). Observe and record the pressure reading in either psi or kPa.

   Check the pressure specification listed for the applicable vehicle and engine. If the pressure recorded is lower than the minimum specification listed, replace the flow control valve in the pump.

   If the pressure recorded is above the maximum specification listed, the flow control valve in the pump should be removed and either cleaned or replaced.

8. Increase the engine speed from idle to approximately 1500 rpm. Observe and record flow, (gallons/min.) (liters/min.).

   If flow exceeds the specified maximum free flow, the flow control valve in the pump should be removed and cleaned or replaced.

9. Check idle speed, and set to specification if necessary. With the engine at idle, turn (or have an assistant turn) the steering wheel to the left and right stops. Record the pressure and flow at both stops.

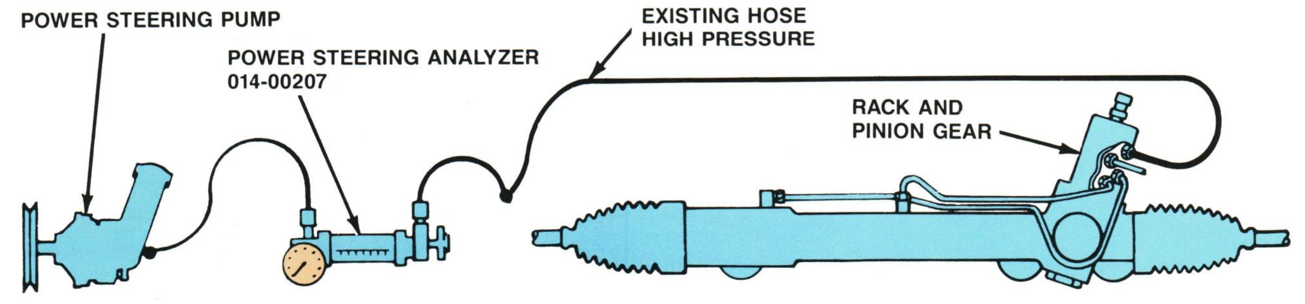
   Pressure developed at both stops should be nearly the same as maximum pump output pressure.

   At the same time, the flow should drop below .5 gallon/min (1.89L/min.). If the pressure does not reach maximum output or the flow does not drop below .5 gallon/min. (1.89L/min.), excessive internal leakage is occuring. Remove and disassemble the steering gear. Replace damaged or broken parts. Pay particular attention to the rack piston and valve seals for damage.

10. Turn (or have an assistant turn) the steering wheel slightly in both directions, and release it quickly while watching the pressure gauge. The needle should move from the normal back pressure reading and snap back as the wheel is released. If it comes back slowly or sticks, the rotary valve in the steering gear is sticking.

    Remove, disassemble, and clean the rotary valve. If the system is severely contaminated, the gear hoses, control valve, and pump must be completely disassembled and cleaned before reassembly.

NOTE: If the problem still exists, check ball joints, linkage, etc.



INSTALLATION OF THE ANALYZER AT THE PUMP OUTLET IS PREFERRED. IF IT IS DIFFICULT TO ATTACH THE ANALYZER AT THE PUMP, IT MAY BE INSTALLED AT ANY CONVENIENT LOCATION BETWEEN THE PUMP AND THE GEAR

TYPICAL INSTALLATION

Figure 115 — Typical Power Steering Analyzer Connection

CETANE TESTER

The cetane tester (Fig. 116) is used to determine the quality of diesel fuel. The cetane number is a measure of the volatility (how readily the fuel will ignite) of the fuel. A good rule of thumb is that the higher the cetane number, the more readily the fuel will ignite in the hot air of a diesel engine's combustion chamber.

The cetane number of diesel fuel is determined by measuring its specific gravity at temperatures between 75°F and 95°F (24°C and 35°C). Poor fuel quality can affect diesel engine performance. Poor fuel quality can also affect ignition timing. For this reason, the cetane number of the fuel should always be checked before performing diesel dynamic timing procedures.

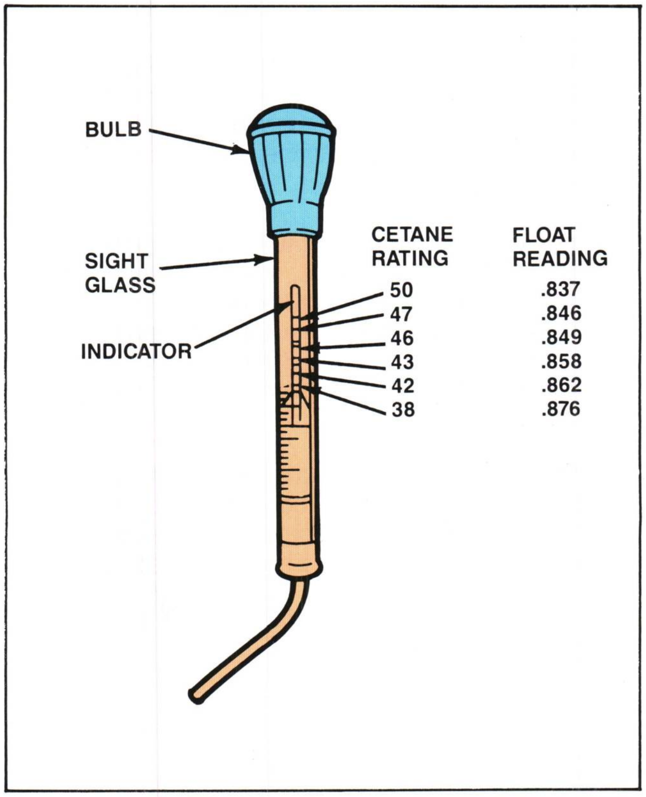


Figure 116 — Typical Cetane Tester

Checking the Cetane Value of Diesel Fuel (Typical)

To check diesel fuel quality using a cetane tester, perform the following procedure:

1. Obtain a fuel sample from the vehicle or stationary tank which is being tested.
2. Squeeze the bulb of the tester and draw enough diesel fuel into the tester to float the indicator inside the sight glass.
3. Gently spin the tester to break the surface tension of the fuel inside the unit.
4. Read the indicator by aligning the lowest point of the fuel level with the mark on the indicator.
5. Record the reading (Fig. 117) and compare it to the cetane value conversion chart (Fig. 118) to obtain the cetane number.

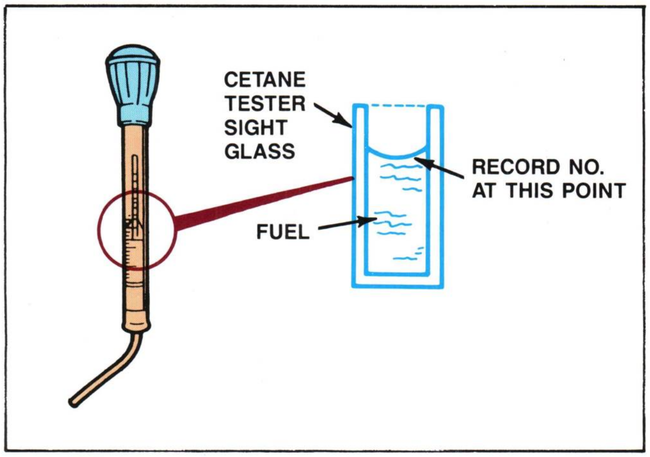


Figure 117 — Reading the Cetane Tester

Hydrometer Reading	Cetane Value
.837	50
.846	47
.849	46
.858	43
.862	42
.876	38

Figure 118 — Typical Cetane Value Conversion Chart

TV PRESSURE GAUGE SET

The Throttle Valve (TV) pressure gauge set (Fig. 119) is used to check the operating pressures of various automatic transmissions. Pressure testing with the gauge set determines whether the specified hydraulic pressure exists in various passages at the correct time.

Most kinds of automatic transmission failures list poor shift quality or shift timing as a symptom. Normal wear, blocked filters, poor adjustment or fluid contamination can all result in the application of components at the wrong time.

Automatic transmissions are equipped with pressure test ports (Fig. 120). By unscrewing a plug from the desired port, the pressure gauge set can be connected to various hydraulic circuits within the transmission. The transmission is then operated in all ranges to obtain operating pressure readings. These readings are compared to specifications (Fig. 121), and possible malfunctions are diagnosed. The pressure tests provide diagnostic information that make it possible to estimate the cost of repairs before the transmission is disassembled.

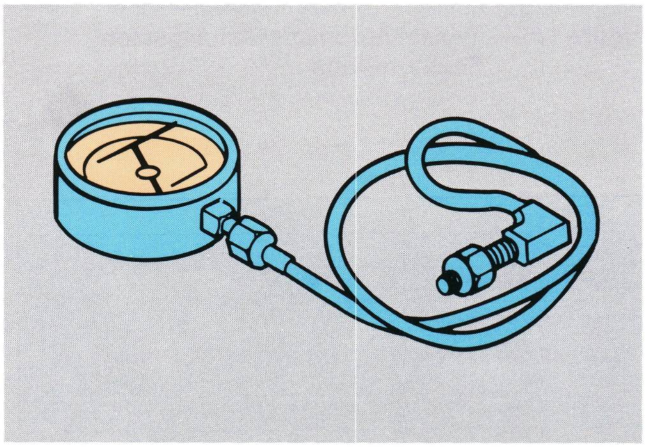


Figure 119 — Typical Throttle Valve Gauge Set

Control Pressure Test (Typical)

Line pressure and throttle pressure on the Automatic Overdrive transmission are tested in the idle position (zero TV) and wide-open throttle position. In each of the two modes, the reverse specifications will be higher than the others.

Control pressure specifications can be found in the Special Specifications booklet.

1. Be sure the TV linkage is properly adjusted.
2. Connect a 300 psi (2000 kPa) gauge to the line pressure port located on the LH side of the case, above the control levers (Fig. 120). Connect enough flexible hose to the transmission to make the gauge accessible while operating the engine.
3. Connect a 0-100 psi (0-690 kPa) pressure gauge to the TV port on the RH side of the case (Fig. 120). Connect enough flexible hose to the transmission to make the gauge accessible while operating the engine.

   CAUTION: Pressure gauges affect the shift quality of the transmission. Care should be taken not to accelerate or decelerate rapidly. Possible transmission failure could result.

   NOTE: WOT reading are to be made at full stall. However, be sure to run the engine at fast idle in NEUTRAL to allow transmission cooling between tests.

4. Run the engine until it is hot.

   CAUTION: Idle pressure must be read with the throttle off the fast idle cam.

5. Apply the service and parking brakes firmly and shift through all the ranges. Record the line pressure and throttle pressure. Compare the pressure readings obtained with specifications (Fig. 121).

After performing the control pressure tests, analyze the results related to the condition in the following chart.

Keep in mind that clutch and servo leakage may or may not show up on the control pressure test. This is because the pump has a high output volume and the leak may not be severe enough to cause a pressure drop; and orifices between the pump and pressure chamber may maintain pressure at the source, even with a leak downstream. Pressure loss caused by a less than major leak is more likely to show up at idle than at WOT, where the pump is delivering full volume.

Conversely, if you are manipulating the TV linkage to simulate WOT, but actually testing at idle, the leak is more likely to cause a pressure loss in the WOT position.

To further isolate leakage in a clutch or servo circuit, it is necessary to remove the oil pan and valve body to perform case air pressure tests.

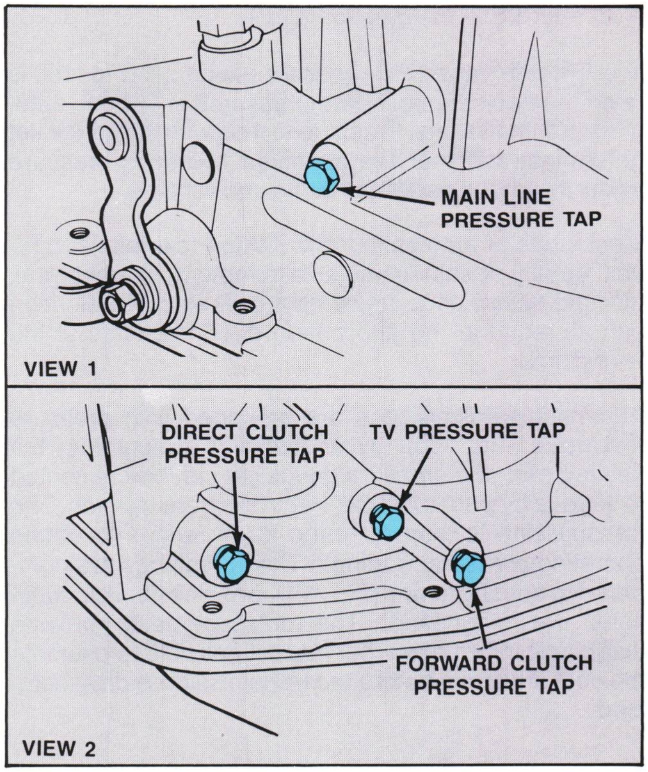


Figure 120 — Typical Automatic Transmission Pressure Taps

Control Pressure Condition	Possible Cause(s)
Low in P	Valve body bolts loose, main oil regulator valve sticking, low reverse servo leakage.
Low in R	Reverse clutch leakage, low reverse servo leakage.
Low in N	Valve body bolts loose, main oil regulator valve sticking.
Low in Ⓓ	Forward clutch leakage, overdrive servo leakage, valve body bolts loose, main oil regulator valve sticking.
Low in D	Forward clutch leakage.
Low in 1	Forward clutch leakage, low. Reverse servo leakage.
Low at idle in all ranges	Low fluid level, restricted oil filter, loose valve body bolts, pump leakage, case leakage, valve body leakage, excessively low engine idle, fluid too hot, main oil regulator valve sticking.
High at idle in all ranges	T.V. linkage, valve body (throttle valve or main oil regulator valve sticking).
OK at idle but low at WOT	Internal leakage, pump leakage, restricted inlet screen, T.V. linkage, valve body (T.V. or T.V. limit valve sticking, main oil regulator valve sticking).

Figure 121 — Typical Control Pressure Diagnosis Chart

HYDRAULIC MEASURING DEVICES

ANTI-LOCK PRESSURE GAUGE

The anti-lock pressure gauge is used to check the operating pressures of anti-lock brake systems. Typical diagnostic uses of the anti-lock pressure gauge include: measuring the threshold of the brakelamp pressure warning switch (PWS), checking accumulator precharge, and checking the hydraulic unit for leakage.

NOTE: Refer to the applicable shop manual before performing any service or diagnosis procedure on an anti-lock brake system. Follow all applicable safety precautions while servicing the system.

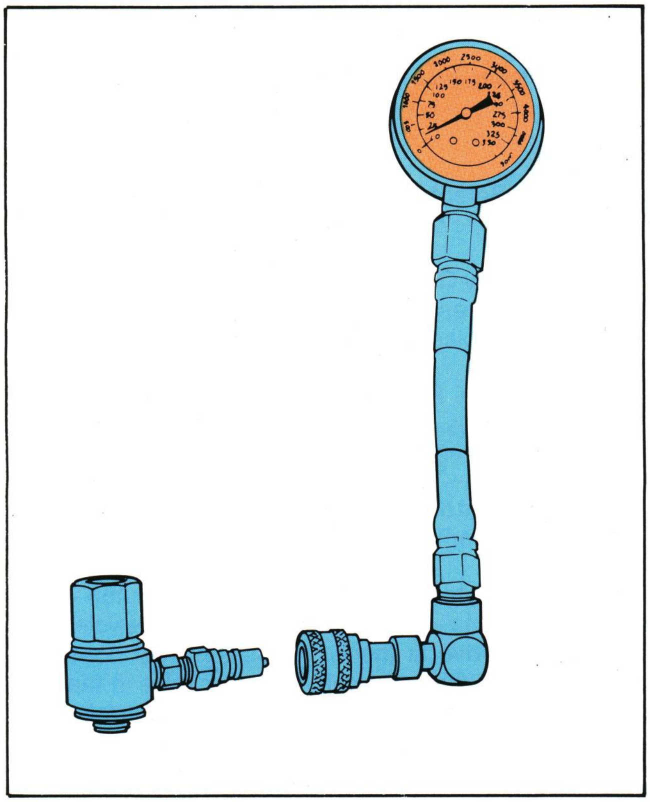


Figure 122 — Anti-Lock Pressure Gauge

Brakelamp Circuit Pressure Warning Switch Test (Typical)

To check brakelamp circuit Pressure Warning Switch (PWS) operation, perform the following procedures:

WARNING: PRIOR TO HYDRAULIC ACCUMULATOR REMOVAL, YOU MUST ENSURE THAT THE PRESSURE SYSTEM IS DISCHARGED. THE HYDRAULIC ACCUMULATOR CONTAINS BRAKE FLUID UNDER HIGH PRESSURE.

1. Discharge the brake system as follows:
   a. Turn the ignition switch to the OFF position.
   b. Pump the brake pedal at least 20 times until you feel it become "hard."
2. Wrap a clean cloth around the base of the accumulator to absorb residual brake fluid during accumulator removal.
3. Remove the hydraulic accumulator.
4. If necessary, disengage the engine wiring harness from its routing clip on the dash panel. Set the harness aside.
5. Install the anti-lock brake pressure gauge adapter and pressure gauge onto the hydraulic unit (Fig. 123). Install the hydraulic accumulator.

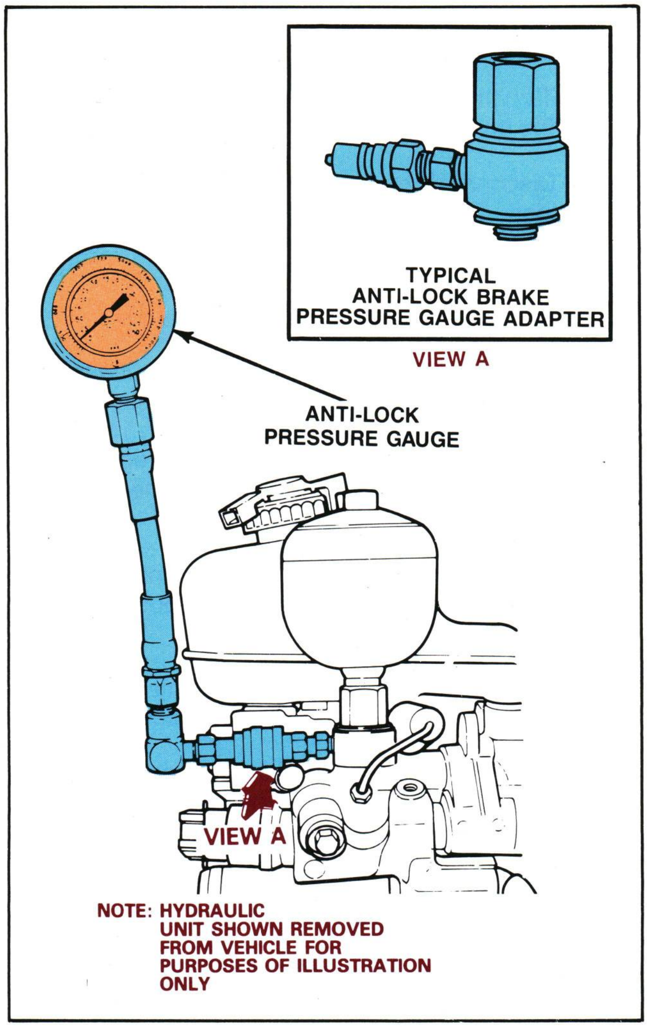

TYPICAL
ANTI-LOCK BRAKE
PRESSURE GAUGE ADAPTER
VIEW A
ANTI-LOCK
PRESSURE GAUGE
VIEW A
NOTE: HYDRAULIC UNIT SHOWN REMOVED FROM VEHICLE FOR PURPOSES OF ILLUSTRATION ONLY

Figure 123 — Anti-Lock Pressure Gauge Installed onto Hydraulic Unit (Typical)

WARNING: DO NOT DISCONNECT THE ANTI-LOCK HIGH-PRESSURE GAUGE WHILE THE SYSTEM IS UNDER PRESSURE.

6. Connect the pressure warning switch 5-pin electrical connector if necessary.
7. Turn the ignition switch to the RUN position.
8. When the pump motor stops, disconnect the PWS 5-pin plug if necessary.
9. Depressurize the hydraulic accumulator by slowly pumping the brake pedal until continuity exists at the specified electrical connector.
10. Observe the hydraulic pressure gauge when continuity is reached.
11. If you missed the reading or want to reverify the reading:
    a. Connect the 5-pin plug.
    b. Turn the ignition switch to the RUN position until the pump stops.
    c. Disconnect the 5-pin plug and reverify the readings.

FUEL INJECTOR TESTER/CLEANER

When diagnosis of the fuel injection system indicates a fuel injection problem, the Fuel Injector Tester/Cleaner can be used to test and clean the injectors. The tester/cleaner is equipped with an internal pump, regulator, filters, reservoir and controls. The tester/cleaner offers the following features and advantages:

- The technician can thoroughly clean and accurately test the electronic fuel injectors without removing them from the vehicle.
- Various adapters allow the Fuel Injector Tester/Cleaner to be used on a variety of vehicles.
- The technician can test each injector against the flow pattern designated for a new injector. Thus, the technician can detect faulty injectors.
- The unit incorporates a flowmeter which is calibrated for various injectors.
- The unit can also be used for bench testing injectors.

The Fuel Injector Tester/Cleaner contains the following components:

- **Flowmeters** — The flowmeters display the amount of fuel flow through the injectors. Red balls indicate the fuel flow level. Colored bars indicate acceptable flow ranges for various injectors.
- **Flowmeter Selection Valve** — The selection valve selects the appropriate flowmeter for various injectors.
- **Injector Test Switch** — The spring-loaded injector test switch allows the operator to pulse the injector during testing.
- **Purge Switch** — Use the purge switch during bench testing only. It is used to purge air from the fuel line and injector.
- **Injector Selector Switch** — Use this switch to select the injector to be tested.
- **Fuel Supply Outlet** — This outlet supplies the injectors with pressurized fuel during the testing and cleaning cycles.
- **Fuel Return Fittings and Return Lines** — The return fittings and lines allow fuel to recirculate through the tester/cleaner.
- **Fuel Regulator** — The fuel regulator adjusts the fuel pressure supplied by the tester/cleaner.
- **Manual Shutoff Valve** — The manual shutoff valve controls fuel recirculation within the tester/cleaner. With the valve in the OFF position, fuel does not recirculate within the unit. With the valve in the ON position, fuel recirculates through the tester/cleaner.
- **Wiring Harness Connector** — Attach the fuel injector harness to this connector.
- **Power Supply Line** — Attach this line to the vehicle battery to power the tester/cleaner.
- **Fuel Tank** — Fill the tank with fuel during the injector test cycle, or with a mixture of fuel and injector cleaner during the cleaning cycle.
- **Pressure Gauge** — The pressure gauge displays tester/cleaner fuel supply pressure.
- **ON/OFF Timer Switch** — This is a two-position switch. In the ON position, the unit will run for approximately ten minutes, then shut off automatically.

- **Indicator Light** — The indicator light glows steadily when the unit is on. It flashes when the unit is off. If flashes to indicate that the unit is connected to a power source. The light will not glow unless the unit is connected to a power source.
- **Continuous Fuel Injector Switch** — This switch permits the tester/cleaner to be used on K-Jetronic-type injection systems.

The tester/cleaner includes several hoses and adaptors which permit connection to various vehicles. The injector tester/cleaner also includes the following components: a turnbuckle for idle speed adjustment; an injector harness continuity checker; an injector bench test fixture; and various injector adaptor harnesses.

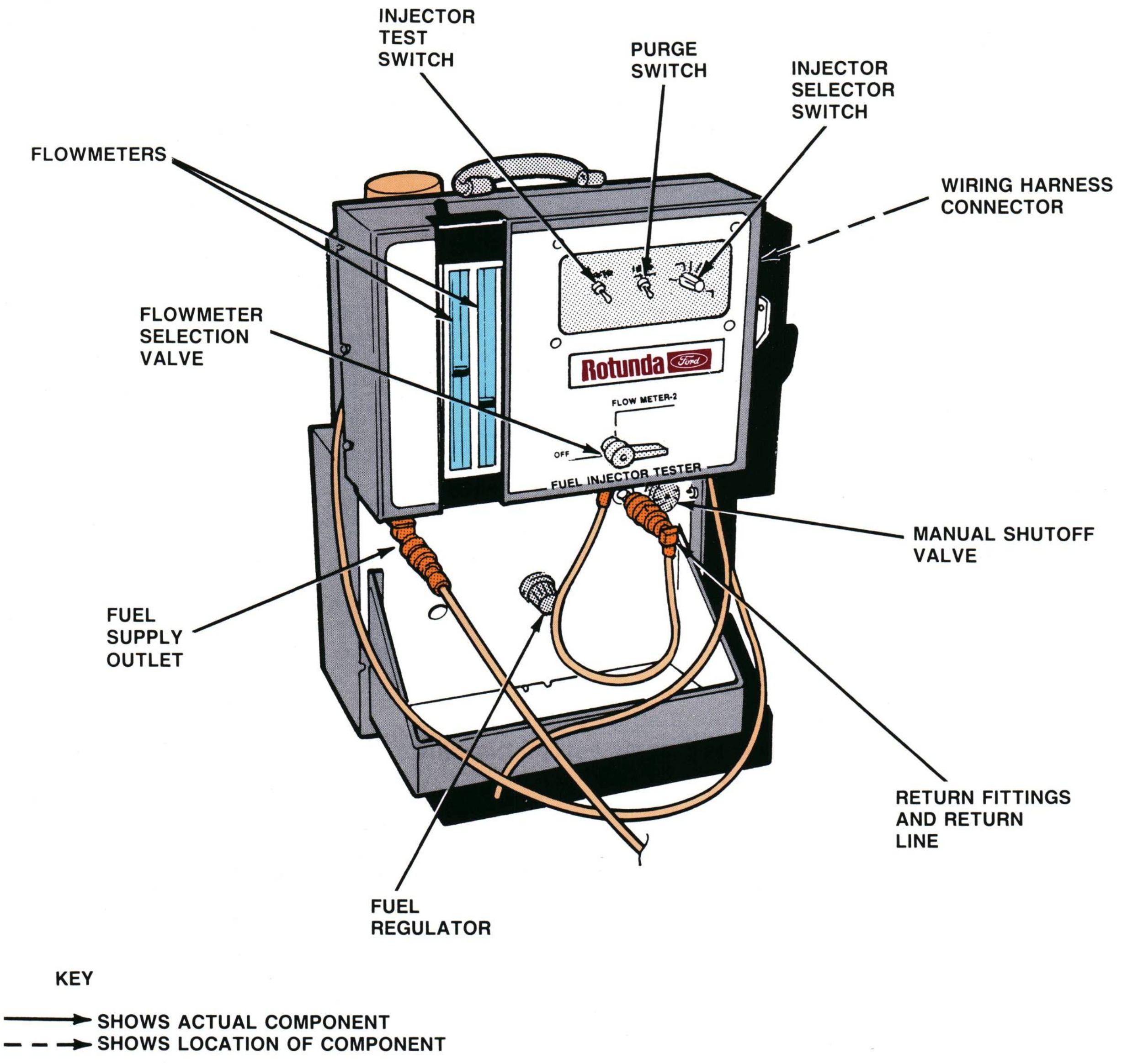


Figure 124 — Fuel Injector Tester/Cleaner Component Identification

Fuel Injector Testing

WARNING: NO SMOKING OR OTHER OPEN FLAME OR SPARK IS ALLOWED WHEN WORKING WITH THE ROTUNDA FUEL INJECTOR TESTER/CLEANER. THE FUEL INJECTION SYSTEM OPERATES AT A HIGH PRESSURE. NEVER DISCONNECT ANY FUEL LINE OR SYSTEM COMPONENT WITHOUT FIRST RELIEVING THE SYSTEM PRESSURE AS DESCRIBED IN GROUP 24 OF THE SHOP MANUAL.

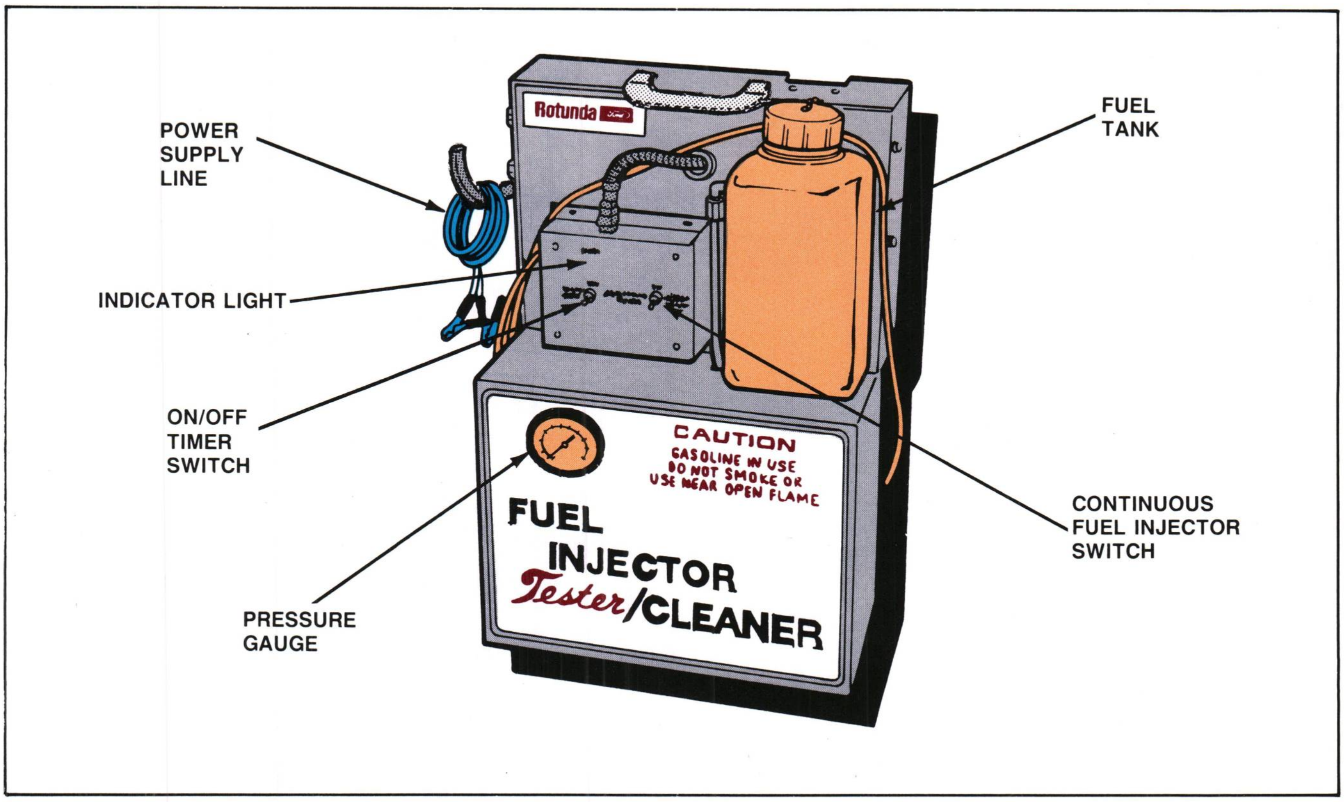


Figure 125 — Fuel Injector Tester/Cleaner Component Identification

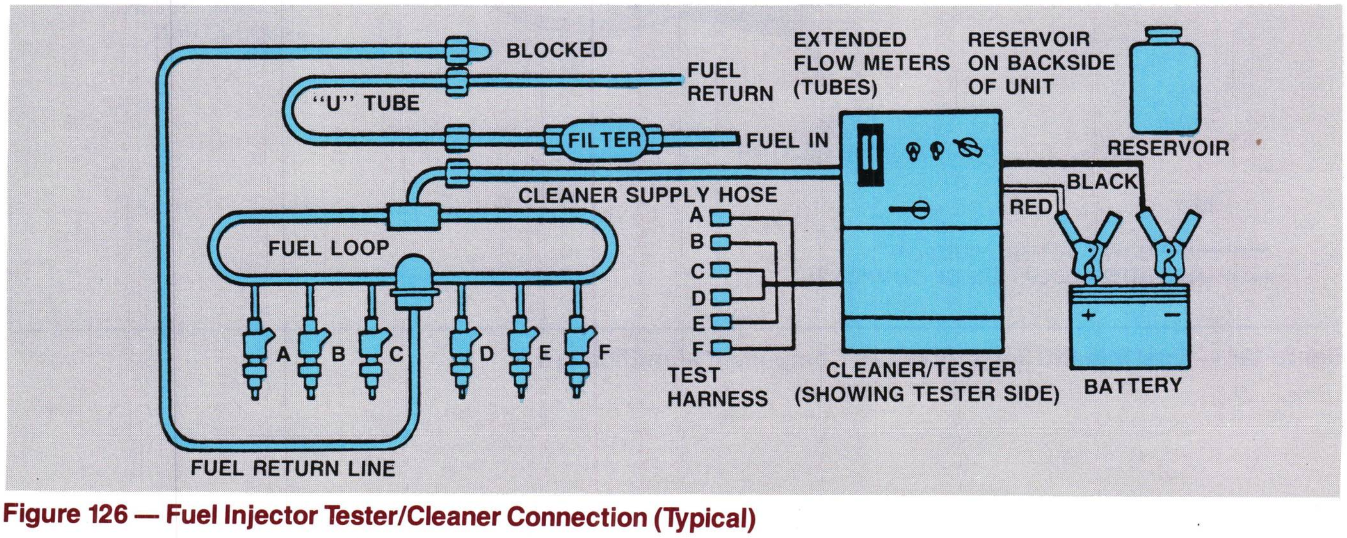


Figure 126 — Fuel Injector Tester/Cleaner Connection (Typical)

FUEL QUALITY TESTER

Poor fuel quality can be responsible for many driveability problems. Fuel quality related driveability problems include: hard starting (hot or cold), stalling, surging, hesitation and rough idle. If normal diagnostic procedures fail to locate the problem, check the fuel quality. A check of fuel quality can often avoid costly and unnecessary component replacement.

A common fuel quality problem consists of excessive alcohol content. The Fuel Quality Tester allows you to measure the alcohol content of a fuel sample. After measuring fuel alcohol content, you can determine the effect that fuel alcohol content has on driveability and component deterioration complaints.

The following test method should not be considered to be scientifically accurate. The tester does not differentiate between types of alcohols. However, the tester gives a good indication of fuel alcohol content. This indication is sufficient for most diagnostic purposes.

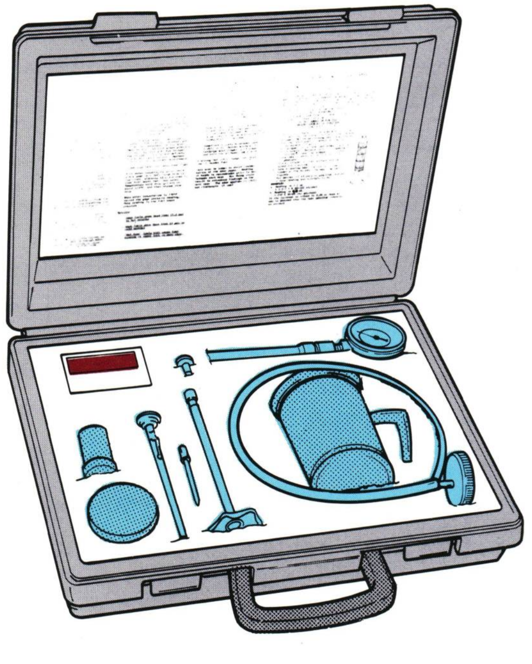


Figure 127 — Fuel Quality Tester

Fuel Alcohol Test

1. Pour fuel sample into a small clean container (beaker, etc.).
2. Carefully fill graduated cylinder to indicated level. Refer to tester instructions if necessary.
3. Add indicated amount of water to the graduated cylinder. Use a calibrated eyedropper to add water.

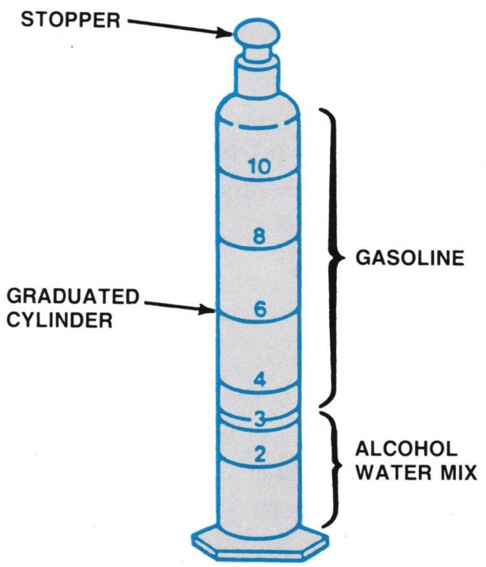


Figure 128 — Adding Water To Fuel Sample

4. Insert stopper into cylinder. Shake cylinder vigorously for one minute. Relieve pressure in cylinder by periodically removing stopper.

   NOTE: Alcohol dissolves in water. This solution will drop to the bottom of the graduated cylinder.

5. Place the cylinder onto a flat surface. Let it stand for one minute.
6. Take a reading at the boundary line between the two liquids.
7. Use the mathematical formula described in the operating instructions included with the tester to determine fuel alcohol content.

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